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OF

PORTO RICO

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OF

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CITRUS DISEASES OF PORTO RICO.[1]

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INTRODUCTION.

The citrus industry in Porto Rico, in so far as the production of fruit for export is concerned, dates from about 1902, and for a number of years was confined to orange growing almost exclusively, grapefruit production not having reached a figure of any importance until 1907. The early exportations were from seedling trees growing in groups, or as scattered specimens through the upland coffee districts of the Island, where they were used to a considerable extent for shading the coffee, fruit production being a secondary consideration. Limes and lemons existed as individual trees for a home supply only, and the grapefruit was practically unknown.

Once initiated, the planting of citrus groves, for the most part limited to several varieties of oranges, was taken up rapidly, and before many years extensive groves were in existence along the north coast between Carolina and Arecibo. For a number of years attention was concentrated on the orange, but the grapefruit rapidly came into favor, so that for the past few years practically nothing but the latter fruit has been set in new groves, or extensions of old ones.

Moreover, the practice of budding over orange to grapefruit has been common. so that at the present time the production of grape-

[1] This paper is based on the work carried on by the writer as part of his official duties over a period of nearly four years. Acknowledgment is made of assistance received to Mr. R. C. Rose, assistant pathologist now on leave for war service; to Mr. W. V. Tower, formerly director, for encouragement at all times; to the citrus growers of the Island who have shown all possible courtesies in the course of the field work; and to the Porto Rico Fruit Exchange, which has given most substantial assistance to the project.

In order that the greatest possible amount of information on the various diseases might be presented to the growers, the publications of the experiment stations of Florida and California, and of the United States Department of Agriculture, as well as other sources, have been drawn upon, where the matter contained was applicable to local conditions.

fruit greatly exceeds that of cultivated oranges. The continued heavy marketing of the so-called wild oranges will explain the large total of the orange exports. The basic reason for the change from orange to grapefruit in the cultivated groves has been economic, better returns at lower cost of production having been realized from the latter fruit in the opinion of most growers.

The progress of the industry, and the relative importance of the two fruits is graphically shown by the following table, which gives the value of the exports from 1901 to date:

Value of Exports of Citrus Fruit from Porto Rico.[1]

Year	Orange	Grapefruit
1901	$84,475	
1902	51,364	
1903	230,821	
1904	352,646	
1905	125,422	
1906	295,63[illegible]	
1907	469,312	$7,586
1908	630,720	44,535
1909	401,912	76,310
1910	582,716	162,749
1911	703,969	309,698
1912	584,414	525,048
1913	740,091	762,811
1914	752,180	751,769
1915	378,181	834,440
1916	790,797	837,014
1917	1,009,737	939,677

[1] From Report of the Governor of Porto Rico, 1917.

Limes, lemons, or citrus varieties other than oranges and grapefruit, have, as already noted, never been grown on any extensive scale, the trees being limited for the most part to individual specimens for domestic purposes only. At no time have shipments been sufficient to warrant separate statistics.

In the early years of the industry, lemon culture was tried by a number of growers, and some quite extensive groves were set out, but on the north coast at least no success was attained. This was due to the ravages of foot-rot and scab, and to cultural conditions, lemon growing requiring considerable skill. The growing of this fruit could beyond much doubt be carried out most successfully in the irrigated sections of the south coast by anyone possessing the requisite knowledge.

Progress of disease investigations.

It has been true, most unfortunately, that along with the rapid development of the citrus industry certain diseases, several of them very severe, have made their appearance. As early as 1901 the presence of scab was mentioned in the first report of the Mayagüez Experiment Station, and in several succeeding reports, particularly those for 1903, 1904, 1909 and 1913, reference was made to this and other citrus diseases.

Investigations commenced in 1915 by this Experiment Station, revealed that for a considerable period the groves had been suffering from the attacks of certain diseases, particularly scab and foot-rot. The first disease to assume importance was foot-rot, which for a time took on an epidemic character, but had by 1914 practically subsided as a result of the use of resistent stocks and improved cultural methods.

The situation with regard to fruit rots or shipping rots became so serious that in 1913 help was asked of the United States Department of Agriculture. Observations were made of the condition of the fruit as it appeared on arrival at New York, and the fungi involved were studied in the laboratories at Washington. Mr. C. W. Mann, of the Bureau of Plant Industry, was sent to the Island and made a tour of the citrus-growing sections to investigate the status of affairs here. The report of his work has been published as Bulletin No. 7 of this Station.

Since about 1913, the scab situation has been serious, the bulk of the fruit of some growers commonly being so badly disfigured as to be unsalable, excepts as culls. Other diseases, of minor importance in themselves, have in the aggregate produced no inconsiderable losses.

It is impossible to arrive with any degree of accuracy, at the total loss to be charged to diseases, so many separate items composing the whole, and this being in turn so intimately connected with the damage to be charged to insect pests and mechanical injuries. Then again, the loss from many diseases—for example, die back or bark rot, which lessen the crop production over a series of years, or may even destroy a tree—cannot be figured on any definite basis.

A very rough estimate, but at the same time a most conservative one, will place the annual financial loss suffered by the growers and to be charged to the various diseases including shipping rot, at five per cent of the crop, or approximately $100,000. In the case of

the wild orange crop this estimate is very low, the loss from shipping rots alone commonly amounting to ten per cent, and often going as high as fifty.

The need for investigation of the citrus diseases was recognized, and immediate attention given, following the turning over of the present Insular Experiment Station to the Government by the Sugar Producers' Association. Progress reports and publications have been issued from time to time on certain phases of the problems investigated. These are noted in the bibliography on page 110.

As the work has progressed it has become apparent that, considering the groves as a whole, there is taking place a gradual spread of the various diseases, and that certain ones are becoming more virulent. Several have been discovered of comparatively recent introduction, or at least of recent activity on citrus hosts, and these may at any time assume a virulent state. The increased plantings, for the most part of one species, the grapefruit, and often in practically continuous stretches, tend to favor the increase and spread of injurious fungi.

The entire subject then, and particularly the matter of control measures from the grower's view point, becomes increasingly important. Many who have in the past ignored or given scant attention to the matter of grove sanitation, spraying, and improved cultural conditions, are now confronted with the vital necessity of prompt action along these lines.

While much has been accomplished in disease control in other citrus-producing regions, we find that recommendations applicable there often fail to give results under Porto Rican conditions, and it becomes clear that our disease problems must be worked out in large part here. The life histories of the various fungi involved and the principles of control can be studied out in the laboratories, or in such field experiments as are possible, but the practical working out of control measures lies very largely in the grower's own hands.

Citrus diseases not present in Porto Rico.

Although Porto Rico has an all-too-long list of diseases present in the groves, there are still a considerable number of diseases, recorded as serious, which exist in other parts of the world and have not yet reached the Island.

Probably the best known of these at the present time is the canker, a most virulent bacterial disease of leaves, fruits, and young twigs, which was accidently introduced from Japan into a number of the Southern States some years ago. Several millions of dollars have

been expended in the attempt to eradicate it, and the fight has not been concluded.

Among other diseases which can be mentioned in this connection are the brown rot (*Pythiacystis*), which caused enormous losses to the California citrus industry before a means of control was devised; the cottony rot or mold, attacking the fruit as well as the twigs; several types of gummosis due to fungi not known in Porto Rico; and a new bacterial disease of twigs, citrus blast. In Florida there is a disease known as nail-head rust or scaly bark, due to a certain fungus also as yet unknown to us. Jamaica reports a fungus gall on the branches, and in Ceylon a powdery mildew is so serious that it is said to be impossible to raise citrus fruits even for home consumption.

A considerable number of other diseases, all capable of causing heavy damage, could be mentioned, but these few will suffice to bring out vividly the importance of keeping at arm's length, by means of quarantine, any addition to the already formidable list of Porto Rican citrus diseases. Growers can cooperate most effectively in this important work by not attempting to import any citrus stock, and by reporting anyone who does. Specimens of any unknown disease, or type of injury appearing in the grove, should be sent to the Experiment Station for determination. Quick action in cases of this kind will make it possible to check a new disease in the incipient stage.

In studying the diseases of citrus in Porto Rico, it speedily becomes apparent that they are much the same as those reported for Florida, differing on the other hand very widely from those of California. That this should be the case seems reasonable, when it is remembered that the bulk of the groves of the Island originated directly or indirectly from budwood brought from the former State. There is, as might be expected, an even greater similarity to conditions existing in Cuba and the Isle of Pines, since the industry in those islands is but an offshoot of that of Florida, and in addition the soil and climate of Porto Rico and Cuba are much alike. Certain diseases, black melanose for example, which are of very minor importance or non-existent on the mainland, occur in the two regions.

In presenting the following information at this time, it is realized that to a considerable extent it is fragmentary, and that much intensive work remains to be done; but it has been prepared in the hope that such data as is available will be of sufficient value to

warrant its publication, and that it may serve as a basis for future work by pointing out the problems yet unsolved.

GENERAL CONSIDERATIONS.

Before taking up the specific diseases, there are certain general considerations which will be treated in some detail, since they are of the utmost importance to the growers. These, in brief, are the relation of cultural practices to health and disease in the grove, and general account of methods of control and prevention.

It is most difficult to draw a line between health and disease in plants. In a broad sense a tree may be said to be sick or diseased when it departs from the normal, but here again the difficulty is encountered of determining just what constitutes a normal tree. The normal of certain groves would in others be considered as decidedly abnormal. Without attempting to settle the question, consideration will be given to such abnormalities or injuries as are capable of causing, either directly or indirectly, financial loss by cutting down yield or rendering fruit unsalable.

Disease in a broad sense may be due to any one of a great variety of causes, principal of which, as far as the present subject is concerned, are those due to fungi, insects, cultural conditions, and physiological or unknown causes, the last so intimately connected with the preceding point as to be hardly separable. Insect injuries, while serious, are excluded from this paper, their study coming in the field of entomology. Bacterial diseases, though serious in other regions, are fortunately as yet unknown, or of negligible importance, in Porto Rico. A detailed exposition of the specific deseases due to fungi or to unknown causes will constitute the body of this paper.

This leaves for consideration at this point the important topic of the effect of cultural practices on disease. This will be of particular value at this time, when so many of the groves are suffering from an apparent decadence, although still comparatively young. It is the writer's belief that the cause for this condition lies in neglect or faulty application of the points about to be considered.

RELATION OF CULTURAL PRACTICES TO DISEASE.

Many growers fail to realize the effects, both direct and indirect, that cultural practices (cultivation in a broad sense) can have on the general health of their groves, and the resulting amount and character of the fruit produced. There are indeed several common diseases, of no little importance, which are directly accounted for by

neglect of these principles, and the disease is rare that is not influenced to some extent by them. It is too often the common attitude to expect the plant pathologist, or extension worker, to provide some cure which will eliminate in short order all the ills the grove is heir to; and there has been much disappointment when not only was such a cure not provided, but suggestions were made that what was needed was improvement in cultural practices.

SELECTION OF A GROVE SITE.

The first point to be given attention is the matter of selecting a grove site. The question of the character of the soil, or the soil type, is of minor importance, since citrus can be grown on a very wide range of soils, but the depth, possibilities of drainage, and related points must be carefully looked into. More than one grove in Porto Rico has been set in land where hardpan, or even rock ledges, were so close to the surface as to effect the growth of the trees within a few years. Hardpan is the reason for a number of decadent groves at the present writing. Even where the trees are not checked completely in their growth, they are so weakened as to fall easy prey to various diseases.

Of equal importance is the necessity of thorough drainage. Citrus trees are very susceptible to injury by standing water around their roots, and irreparable damage can be done by a sudden rise in the water table, or by flood water, in a few days' time. Where there is persistently poor drainage not only do weakened trees result, but the way is opened by the death of the roots to attack by specific diseases of the roots and crown.

In some districts drouths are of common occurrence, and it would be most advisable to arrange for irrigation where possible. This would provide for maximum, normal growth at all times. Here again, trees weakened by lack of moisture not only fail to make desired growth, through the loss of leaves, but the resulting weakening paves the way for withertip and similar troubles. A most direct result of drouth is of course the dropping of a large proportion of the fruit before maturity, or at such times as shipment is impossible.

Still another point, while on the topic of site selection, is that of slope. Blocks of trees set out on even moderate slopes thrive poorly, or even at times prove utter failures, where the soil is light and hence easily washed away, or where on heavier soils such precautions as are necessary to prevent this are not taken. Hillside groves are entirely feasible, if the grower cares to go to the trouble and expense

of installing a system of terraces, which will retain the soil around the roots; otherwise such sites are better avoided, or abandoned if already planted.

THE NURSERY AND PLANTING STOCK.

Too much attention cannot be given to selection of planting stock, since a productive grove is hardly possible without a solid foundation in the way of healthy trees from the nursery. Where time is available it will pay each grower to produce his own trees, thus assuring himself of healthy, vigorous trees of known variety and productive parentage. If this is not possible, a careful inspection before purchasing should be made of the nursery from which the trees are to come, to make certain that they are free of serious diseases or insect pests. In the event that diseases or insects are present, thorough spraying, pruning, or other corrective measures should be insisted upon before delivery. In addition the nurseryman should give a written guarantee as to variety.

In establishing nurseries, a site as far as possible from existing groves should be selected, in order that the rapidly growing seedlings may be kept free from infection by disease, or infestation by insects. The custom of planting nursery stock between the grove trees is particularly undersirable, not only because of the disease problems, but for other important considerations as well.

It need hardly be said that all possible care in cultivation and fertilizing will be amply repaid by the increased health of the trees, and their resistance to attack by fungi or to unfavorable growth conditions, when set in the grove.

A point deserving the greatest attention, although not directly related to the subject in hand, is the improvement of the industry by bud selection. Of late years considerable attention has been given to this phase of the work in California, and its value has been fully demonstrated by the studies of Dr. Shamel, of the United States Department of Agriculture. Briefly, this work consists in obtaining "tree-performance" records over a period of years (that is, the actual production as well as the character of the fruit of each tree) and then using for propagating material, buds from those trees that have given the highest yield of the desirable grade of fruit. This subject is discussed in detail in Farmer's Bulletin No. 794, which is distributed free by the United States Department of Agriculture, and will well repay a careful perusal.

As the work with citrus diseases progresses attention will be given to the possibility of checking certain of them by using buds from

resistent trees. The grower could well afford to give this matter some attention by searching for trees of this nature.

PLANTING IN THE GROVE.

The actual setting of the young trees in the grove involves a number of factors, which have a more or less direct bearing on the future health of the trees, and their resistance to disease. Care is necessary to prevent a drying out of the roots through too long exposure to air, and all broken or injured roots should be cut away, leaving smooth, clean wounds. Treatment of these cuts will hardly be practicable or necessary because of their small size. Such points as careful preparation of the soil, straightening out of the roots, and planting at such time as to avoid severe drouths, are so obvious as to need no further elucidation.

The practice of setting the trees high, practically on the surface of the ground, so that when the roots are covered a mound of earth results, has much to recommend it, particularly where drainage is at all difficult or uncertain. In the older groves large numbers of trees, set with the crowns level with the surface, have settled so that they are now in basins, which if the soil is at all heavy, hold water for considerable lengths of time. Low setting increases the danger of injury from faulty drainage, and also adds to the possibility of the heaping of soil around the crown and base of the trunk, a condition that favors foot-rot and other bark diseases.

It might be thought that distance of planting would be without effect on the susceptibility to disease. It is, however, true that where trees are so close together as to interlock and so shade the ground completely, the resulting dampness and shade prove very favorable to bark diseases, foot-rot and pink disease in particular.

CULTIVATION.

Little need be said on the subject of cultivation. It will be readily apparent that there is an important relation, though indirect, between the cultivation given in a grove and the amount of disease. In general, the better the cultivation the healthier the trees, and hence their greater resistance to attack by unfavorable influences or parasites. Methods will vary greatly, depending upon age and location of the grove, character of the soil, and other circumstances, so that the actual cultivation practices to give best results are something that each grower should work out for himself by observation and experiment.

WIND PROTECTION.

Wind protection is likewise necessary, since a constant sweep of the wind such as occurs in Porto Rico prevents proper growth, and by favoring the increase of the scale insects paves the way for the anthracnose fungus, and other fungi of a similar nature which attack dying or unhealthy tissues. There is also a direct loss, where proper wind protection is lacking, through scarring, thorn puncturing, and dropping of the fruit.

Although wind protection is essential, it can nevertheless be overdone, or be carried out in such manner as to be harmful. It is a common observation that the use of bamboo means the complete loss of at least two rows of trees, and that from three to four more are influenced to the extent that they grow slowly, are misshapen, produce small crops of fruit, and have a decided tendency to withertip, or a dying back of the crown. This is produced by both the effect of the excessive shading and the strong root development of the bamboo. Ditches sufficiently deep to cut off the roots of the latter are required, and lines should be put in only at such distances as are necessary. In many places, at least every other line can be cut out without harm resulting, and with a saving of at least three rows of trees.

To some extent at least windbreaks, by producing quiet, humid conditions, aid in the spread and development of certain diseases, notably scab. This does not by any means make it desirable to abandon all breaks, but only to eliminate such as are unnecessary.

The ideal windbreak would be one of the leguminous trees, such as the guava (*Inga vera*), which are used for coffee shade. As temporary breaks the gandul (*Cajanus indicus*), the gallito (*Agati grandiflora*), and other shrubby plants are used. The second one named has given most excellent results, and it is especially recommended, being particularly free of diseases. The gandul, so generally used, is subject to a number of diseases, and is suspected of harboring several citrus maladies. Care should be taken to remove the plants of this species at maturity, when used for windbreak.

FERTILIZATION AND LIMING.

Fertilization, like cultivation, has an indirect though important bearing on the subject of disease or unthriftiness in the grove. It is well known also that the kind and quantity of fertilizer used has a direct influence on the quality of fruit produced, excessive nitrogen for example, tending to produce large, thick-skinned, puffy fruit.

Lack of fertilizer becomes readily apparent in the yellowing of the leaves, followed by a dying back of terminal twigs, and it may even induce a tendency to premature dropping of fruit. Certain recognized diseases, or types of diseases, are attributed to excessive amounts of nitrogen supplied in organic form. This point is considered more specifically later.

It is a surprising but true fact that soils of the majority of citrus groves of the Island are decidedly acid, in spite of the fact that they are in large part surrounded by or adjoin limestone hills, and in many cases are cut up by them into irregular-sized blocks. The use of lime to improve the physical condition of the soil, and to supply the other benefits derived from its use, has always been strongly recommended. It has been said, by those who have studied the matter, that, as a general rule, the lime required per acre to neutralize the soil acidity would amount to a considerable number of tons.

Lime may be applied in various forms, such as live lime, air slacked, or ground limestone, the second form being the one most commonly used in Porto Rico. No reports have been received of injury to Island groves from applications of lime in any form. Its use will be of value in promoting a better tree growth, with the accompanying result of more satisfactory yields of disease-free fruit.

A precaution is, however, necessary at this point in view of certain results reported from Florida. It has become apparent there that finely ground limestone, a form but little used as yet in Porto Rico, is capable under certain conditions of producing marked injury to the trees. This injury takes the form of a yellowing of the leaves, partial defoliation, multiple buds, bushy terminal growth, and a dying back. Studies by Prof. Floyd of the Florida Experiment Station have made it seem probable that this trouble is most apt to occur on light soils, and particularly on those lacking in humus. While it is considered doubtful that this trouble will appear here under present conditions, ground limestone should be used in moderation, and in conjunction with any such applications means should be taken to supply humus by growing a cover crop of velvet beans, sword beans, or similar legume, or even by light application of manure. Mulching the trees would also be of benefit.

PRUNING.

It would be foreign to the subject to enter into any discussion of pruning, other than to direct attention to the necessity of removing all dead and dying, or fungus-infected, twigs and branches. This

matter will be referred to in greater detail under various of the specific accounts to follow.

The important topics of picking, packing, and shipping are very directly concerned in their relation to losses sustained in the industry, but as they are more particularly related from a practical standpoint to blue-mold decay, their consideration is deferred to that point.

In the foregoing paragraphs an attempt has been made to outline the relation, often indirect, but none the less important, that cultural practices have in the prevention or control of disease. The grower who gives proper attention to this matter has the battle against the disease enemy half won.

GROVE SANITATION.

In addition to the above considerations, and as a general measure, aimed more or less at all fungus maladies, certain sanitary precautions are of importance, so important in fact that results can not be expected from specific measures if the general principles of grove hygiene are neglected. Briefly these are the removal, by pruning or otherwise, of all fungus-infected material, or that which in the usual course of events would become infected, and the prevention of reinfection by spores or other fungus parts brought in on field crates, wagons, or by implements used in cultivation.

Not only should all prunings be removed or burned, but all dropped fruit should be promptly disposed of. This material has a recognized fertilizing value, and if properly handled, can be used to advantage. In California prunings are sometimes run through portable cutting machines, and cut into small pieces easily incorporated with the soil. If no virulent diseases are present, this method is unobjectionable and could be adopted here. Drops are often buried in the grove, but are so poorly covered that at the first cultivation or even before, they are again exposed, and generally at a time when the rot fungi are sporulating freely. A deep pit at the edge of the grove or near the packing-house is the preferable manner, all things considered, for disposing of worthless fruit.

Simple quarantine measures should be devised to keep out any diseases that have not yet made an entrance, but which are present in neighboring groves. Field crates, wagons, tools, or other items of equipment should not be allowed to enter from infected groves. This matter becomes of more importance at the present day when the sound principle of building community packing-houses is gain-

ing ground. For disinfection of fields crates and other equipment, the most efficient and commonly used substances are corrosive sublimate (mercuric bichloride), copper sulphate solution, and formaldehyde. Formulas and directions for use are given in the appendix.

GROVE DIAGRAMS.

Most growers fail to appreciate the benefit, and even the necessity of having a diagram or plan of each block of trees. The system enables one to keep an exact record of individual tree production, and of other important data, such as character of the fruit, in as great detail as desired. Drone trees can thus be located and eliminated, and bud-selection work is not only greatly facilitated, but absolutely dependent upon some such scheme. From the disease standpoint a plan enables the grower to watch more accurately his sick trees. In brief a grove plan eliminates guess work, and makes for general efficiency in all phases of grove activity. Several schemes have been evolved, varying according to the manner of marking the trees, and to the method of taking and arranging the data. Suggestions and tentative outlines for orchard plans are given in Farmer's Bulletin 794.* The adoption of some plan of numbering trees and taking individual tree data is most emphatically recommended, as a scheme that will pay handsome dividends.

TIME SPENT ON SICK TREES.

As a general problem, which may be taken up at this point, there arises the question of how much effort to expend on a sick tree before removing it. Some growers, especially those with the smaller groves, have a tendency to give considerable attention to attempted cures of such trees, however hopeless their condition, wasting both time and money. It is difficult to determine whether a tree will repay time spent in cutting out diseased tissues, in excessive pruning, or other corrective measures, but as a general rule it seldom pays to spend more than the time and money necessary to remove them.

A young, healthy tree properly planted and cared for, will very soon more than make up in returns for the tree it replaced. This advice will apply in cases of serious foot-rot, root rot, wood rot, scaly bark, and similar diseases. In undertaking that most difficult task, the restoration of abandoned or neglected groves, an interplanting, with the gradual removal of the old wrecks, will be found more feasible than a long, costly, and generally hopeless struggle to bring back the original stand to a productive condition.

SPRAYING.

An important phase of grove practice, and one which with the spread and increase of certain diseases will become increasingly so, is spraying or some system of applying fungicides to the leaves, fruits, and other parts of the tree in order to prevent fungus growth. It is generally overlooked or not thoroughly understood that spraying, as far as fungus diseases are concerned, must be entirely preventive, and can not be curative. This explains in large measure the numerous failures experienced in spraying operations carried out heretofore, although other points also enter into the situation.

Bearing in mind that fungicides must be applied in time to prevent infection, it is clear that the time of spraying must depend upon the periods when infection takes place, or in other words, upon the life histories of the fungi involved. In the specific accounts to follow, an attempt is made to indicate in as great detail as possible the proper time of application of the fungicides recommended.

Another reason for failure in spraying operations is the use of improper materials as, for instance, oil emulsion, which is an insecticide only, when a fungicide is required. In some instances spraying material is used at too great a dilution. A still further source of difficulty lies in the unsatisfactory nature of available labor, resulting in improper application. To secure perfect protection the entire surface of all susceptible growth must be covered with the spray material. This is very difficult, but the more care exercised in the actual spraying operation, the more nearly this ideal is approached and the higher will be the percentage of clean growth. The average laborer tends to miss a considerable proportion of the fruit and leaves of each tree, and to over spray the balance, which results in loss of material and may lead to injury through burning.

The machinery used is often inadequate for the task in hand because of lack of power or other mechanical defects. Improper spray nozzles are often a cause of trouble, particularly in the high-powered machines, where the opening tends to become enlarged by wear, and as a result the liquid is not sufficiently broken up into mist for best results.

Scarcely a grove on the Island is adequately equipped with spraying machinery. A machine or machines that require two or three weeks to cover a grove (provided everything runs smoothly, which is seldom the case) are not sufficient, since efficient control of certain diseases, scab in particular, necessitates more frequent applications.

The make or type of machine is of little importance from our

viewpoint, the requirements being a machine that will give satisfactory, sustained service. To avoid delays, spare parts for engine, and hose and nozzle equipment, should be at hand. Special men should be trained to manipulate the spray leads, and to operate them correctly without waste of material, but in such way as to cover each tree thoroughly. Watch must be kept to maintain sufficient pressure. Material applied in large drops is valueless if not harmful, a fine mist, uniformly applied, being the desired aim. The requisites then for a successful spraying campaign are adequate equipment, and the proper material applied at the proper time, and in thorough manner.

SPECIFIC DISEASES.

DISEASES OF THE SEED-BED.

DAMPING OFF.

Considerable losses are sustained by fungus attack in the seed-bed, by what is commonly known as damping off, since delicate seedlings are peculiarly subject to infection. Several fungi are doubtless involved, acting either independently or together, but the symptoms are practically identical. Infection occurs most commonly near the ground level, and is first noticed as watersoaked areas on the stems, that soon become brown and sunken. Following infection the seedlings fall over and death ensues. Isolated plants are first attacked, but small patches are soon involved, which enlarge and unite if prompt measures are not taken to check the trouble.

Control lies in careful management of the seed beds. The important point in this connection is to provide for thorough drainage. Excessive shading should be avoided. An inch of dry sand applied over the bed at the first appearance of the disease often checks its spread. The greatest possible care must be exercised in artificial watering. Thorough applications at as long intervals as possible are preferable to frequent sprinklings, which wet only the surface of the soil, and so aid the fungus. Since infection takes place at or near the crown of the plant on the ground level, care should be taken to keep this region as dry as possible to inhibit fungus action.

In selecting new areas for seed-beds, land should be taken which has not been used previously for this purpose, or land on which at least, damping off has not occurred. If this is not obtainable, the soil should be sterilized, either by steam applied under pressure for

twenty minutes, or by a one per cent formalin solution applied at the rate of one gallon of solution per square foot of surface. In the latter event the area treated is covered with sacking or other covering for several days to permit the formalin fumes time to act, and the soil is then worked over thoroughly before planting.

CROWN ROT.

True damping off attacks the seedlings only in the very early stages, and before the stem tissues have hardened. Another type of disease similar in its action has been noted which, however, attacked after the seedlings were some months old and had attained a considerable length of woody stem. The bark at the surface of the ground and finally for several inches upward was soft rotted, and the infected plants girdled. This disease also occurred in spots which enlarged rapidly.

The cause was a fungus technically known as *Sclerotium Rolfsii*, which is also the cause of a leaf disease of sugar cane, and a serious wilting of eggplant, pepper, tomato, and other crops. Under very moist conditions the vegetative growth of the fungus itself can be seen at the base of infected plants as a delicate, white membrane, on which are produced the sclerotia, or fruiting bodies. These are hard, globular, and yellow to brown in color, much resembling mustard seeds.

This disease is somewhat more difficult to control than ordinary damping off, but much again can be accomplished by careful drainage and prevention of overcrowding of seedlings, conditions very favorable to the parasite. Seedlings of the age attacked by *Sclerotium* can usually be transplanted, so that the fungus can be headed off by moving all healthy plants to a new location, spacing them properly, and arranging for drainage.

BENCH ROOTING.

A mechanical defect of citrus seedlings of very frequent occurrence is that known as bench rooting or twisting of the root. A similar trouble has been studied in rubber seedlings in Ceylon, and doubtless is to be found in seedlings of other economic plants. The twisting of the root interrupts or interferes with the passage of the sap and so finally may cause a stunting of the tree. It is apparent that these abnormalities originate during the germination of the seed, and are

caused by the inability of the delicate growing point of the young plantlet to force its way through the tough seed-coats in normal fashion. Rocks or other external influences are not concerned.

FIG. 1.—Bench rooting of grapefruit seedlings.

Absolute prevention could be secured by removing the seed coats, but as this is not practical, resort must be had to either planting the seed fresh before they have had opportunity to dry out, or after soaking them from thirty-six to forty-eight hours. This should reduce bench rooting to a minimum.

ROOT DISEASES.

Root diseases to date have caused comparatively little damage, so little, in fact, that practically no attention has been given to a study of this phase of citrus disease, beyond field observations. Losses have never been more than scattering trees, or rarely small groups. For this reason no attempt will be made to distinguish various specific diseases, but the term will be used in a broad sense to cover the loss of trees through any cause operating below ground.

In one grove a number of trees died suddenly and investigation

revealed that a high-water table was the primary cause, it being in some places within two feet of the surface. Neighboring trees on slightly higher land were unaffected. The trees had grown normally for a number of years, until their roots began reaching down below the water level. From this time on they became unthrifty, as evidenced by a yellowing of leaves, and dying back of twigs and branches. After a longer or shorter such period, death came suddenly. The final wilting of the leaves and drying out of the bark often took place within a very few days, as a result of girdling at the crown by a fungus, which had worked up along one or more of the main roots. This fungus (*Ustilina vulgaris*) is very common on dead wood, and is not generally considered parasitic. In the present case it had undoubtedly acted as a wound parasite, gaining entrance through the ends of the roots killed by the water. The fruiting or reproductive bodies were produced around the crown shortly after the death of the tree, as black, carbonous, crust-like layers, pitted with the innumerable openings into the spore sacks. Affected roots and trunks showed a characteristic dry white rot.

No indications have been found at any time of the presence of the truly parasitic root fungi reported from other citrus regions, *Rosellinia* spp., *Sphaerostilbe*, *Fomes*, or *Armillaria mellea*. These fungi are serious for the most part only where there is an abundance of dead wood in the form of logs or stumps seattered through the groves, on which they gain a foothold, and from which they spread to adjoining citrus trees. The fact that most Porto Rican citrus groves have been set in what was formerly open pasture lands of long standing, will make extremely improbable any infection from fungi of this nature. One fungus (*Valsa* sp.) has been commonly noted on exposed roots, and crowns of dead and dying trees. It is also common on dead wood, and beyond much doubt has only been able to attack, as did the *Ustilina*, by working in through wounds, or roots killed by standing water. It produces a dry rot.

In all cases of death of trees in this manner, the first steps should be to look for poor drainage, which is primarily responsible as far as observations to date show. When this cannot be corrected in low-lying sections of blocks of trees, replanting is not advisable, since the same conditions will almost certainly recur. All dead and dying trees should be removed, and care taken to dig out at least all of the larger roots, which would otherwise serve to harbor injurious fungi. Except where drainage is impossible or other factors inter-

fere, replanting almost immediately is entirely feasible, following a thorough working over the soil.

In addition to this type of trouble, due for the most part to faulty drainage, there has been present in a number of grapefruit groves a condition for which it has been impossible to locate a cause. Affected trees become unthrifty, there is a gradually increasing amount of dying back, and after a number of years, death. Older trees only are affected, and in so far as noted only those growing on the lighter sandy soils in the Manatí and Garrochales districts. Individuals may be attacked, or small groups. In the latter case the disease progresses outward from the center, attacking approximately a new line of trees each year. There is some tendency on the twigs to multiple buds, but no gumming, and no fungi are constantly associated with the trouble. A number of measures, particularly variations in fertilizing and cultivation methods, have had no effect. Very severe prunings have only delayed the inevitable death. Where it has been possible to make examinations, the roots have been to a considerable extent dead.

Some observers have associated this malady with Florida blight, which it resembles in some respects, though differing in others. It is not improbable that it is at least a closely related phenomenon. Blight was at one time the most dreaded of all Florida citrus diseases, and caused heavy losses. The cause was never ascertained, and but one recommendation was made with regard to it, to remove and destroy all affected trees as soon as possible. The same advice will apply here.

FOOT-ROT OR MAL-DI-GOMMA.

This is one of the best known and most wide spread of all citrus diseases, having been first noted in the Azores as early as 1834, since which time it has gradually spread to practically all other citrus-growing regions. The damage caused by this one disease in the various parts of the world, where it has been prevalent, will total millions of dollars: the loss in a sixteen-year period (1862–1878) in Italy alone being estimated at two million dollars. Florida has suffered very heavy losses.

The disease has long been known in Porto Rico, it having been in fact the first malady to cause appreciable loss to the industry. Many of the earlier groves, particularly lemon plantings, suffered severely, even to the extent of the loss of a large percentage of the

trees. Of late years, however, the disease has been distinctly on the wane, possibly due to natural influences, but attributed in large part to improved cultivation, use of resistent stocks, and increased knowledge on the part of the growers.

Foot-rot, or mal-di-gomma as it is known to many, is readily recognized. In the majority of cases the first symptom noted will be the exudation of gum at one or more points at the crown or base of the tree. On examination the bark at these points and for varying distances around will be found dead and gum infiltrated, resulting in a deep brown color. The wood beneath infected bark also dies. The disease is accompanied by a very characteristic odor, so distinct at times as to be readily noted some distance from the infected tree. The diseased areas are generally irregular in shape, extending ultimately, if not checked, a distance of one or two feet up the trunk, and a similar distance out along the main roots.

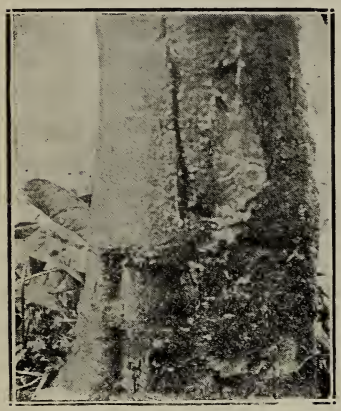

Fig. 2.—Foot rot. Base of grapefruit tree, showing cankers and wood rot of an advanced case.

The disease progresses with great rapidity at certain seasons, commonly during the spring months, and remains more or less dormant at others. During this latter period the tree makes an attempt by the formation of callus to throw off the disease, but is seldom successful, unless aided by the grower. These alternate periods of growth and quiescence result in rough scaly cankers at the crown. A tree will survive one or several seasons following attack, all depending upon the rapidity with which the disease girdles the trunk. The presence of foot-rot is evidenced in the top by a yellowing of the leaves, a general unthriftiness, dying back of terminal twigs, and very often by an exceedingly heavy bloom, which sets very little fruit. Such fruit as is present is dropped in the final stage of the disease, together with the leaves. As would be expected where girdling is involved, the death of an affected tree occurs very suddenly.

Cause.

The exact cause of mal-di-goma has been in some doubt, several theories having been advanced by the numerous workers who have

studied this problem. The Italian botanists have favored the theory of fungus origin, assigning the blame to a white mold-like fungus (*Fusarium limonis*), commonly found in connection with foot-rot cases. This fungus, or one practically identical with it, has also been found in Porto Rico, but it has not been evident through inoculations that it has any causal relation with the disease in question, acting rather as a follower or saprophyte only.

Of recent years, the most widely accepted idea has been that of a non-parasitic, or physiological disease, due to certain environmental factors. Briefly these have been considered to be alternating periods of drought and excessive moisture, close planting, poor drainage and excessive use of organic fertilizers. Observations have quite clearly shown that the disease is more prevalent in lowlands, or where drainage is poor, and that there is undoubtedly a relation between it and close planting. In spite of this, however, it is the writer's opinion, based on observations, that foot-rot is due to a definite fungus (not *Fusarium*), although studies to date have failed to locate it. The progress of the disease from one locality to another, and from tree to tree as well as the result of recent work in Florida, would seem to confirm this theory. The fungus now held responsible in Florida, also occurs in Porto Rico as the cause of a disease of beans and tomatoes, but preliminary inoculation tests have given negative results here.

Control.

It is interesting to note, that the method of handling affected trees is exactly that which would be followed if a fungus were known for certainty to be the cause. In brief this is tree surgery. All diseased bark should be cut away, well back into healthy tissue, using sharp instruments to insure smooth cuts. Care must be exercised that narrow points or bands of diseased tissue running out into normal areas are cleaned out, since otherwise these will remain as infection centers from which the disease will continue to spread. This cutting-out process must be performed not only on the trunk, but out along the main roots as well, in fact wherever diseased tissue exists. It is failure to observe this precaution that has negatived so many attempts at control. The practice has very commonly been to work down to the surface of the soil and there stop. The soil must be dug away from the crown roots, so as to expose them to light and air, and make possible a thorough search for all infected bark. Fol-

lowing treatment the roots should be left exposed for a time at least, and preferably, treated portions should not be recovered at all.

In addition to cutting away infected bark, all discolored wood should likewise be removed with a gouge, or chisel, although this is not so vitally necessary as the first step. The instrument used in this work should be sterilized at frequent intervals by dipping in disinfecting solutions (see appendix). All diseased bark and wood should be removed from the groves and destroyed.

When the wound has been thoroughly cleaned, it should then be protected against reinfection. As a preliminary treatment Bordeaux paste (see appendix for formula) is ordinarily recommended, and is efficient, a thick coating being applied over the entire wound surface. After a week or ten days some permanent covering is necessary, and for this purpose gas tar is recommended, although there are other substances that serve the same purpose more or less efficiently. This phase of the subject is discussed more fully under wood rot. In the majority of cases there is no reason why the tar could not be applied without the preliminary treatment, delaying several days until the wound has dried out somewhat. Where entire roots have been cut away in the work of eliminating infected areas, a corresponding cut in the top will be desirable.

This line of work properly carried out (and it is utterly valueless unless it is properly performed) is an expensive operation, and should not be undertaken when the disease has made any great headway. A common rule of thumb is to take out all trees more than half girdled. The loss in yield in seriously deseased trees, combined with the expense of treatment, make it preferable to replant.

As with many other diseases, much can be done in the way of prevention, and it should be the ultimate aim to control by this means, rather than by the more laborious and expensive cutting-out method. In this connection one of the most successful factors is the use of resistent stocks. As noted, lemon and to a less extent sweet orange roots are most susceptible. Sour orange and grape fruit, on the other hand, are very resistent. A few cases of disease have been noted on grapefruit, but it is thought that it will prove satisfactory as a stock, although it has not been in general use in Porto Rico sufficiently long to judge its ultimate behavior. To avoid foot rot, then, sour orange or grapefruit stocks should be used, particularly when planting in low lands, or where the disease has been prevalent.

As a further step in the same direction, close planting should be avoided, or in old groves, which have closed in, some pruning or even the removal of part of the trees to admit light and permit better air circulation around the trunks will be desirable. When the disease is present, or its presence due to natural conditions is feared, care should also be taken to keep the dirt away from the crown of the tree. A rank growth of vegetation should not be permitted under the trees. A very important point will be to prevent injury to the trunk or roots from hoes, or other cultivation implements.

In Florida excessive applications of organic fertilizers are sometimes supposed to aid the disease, but it is not thought that this possibility need be feared under Porto Rican conditions.

GUM DISEASES, GUMMOSIS.

Several distinct diseases attack the trunk and limbs of citrus trees, with symptoms so similar that much confusion has resulted in attempts at classifying them. Fawcett [1] in a very clear presentation of the subject recognizes seven types of gum disease, of which at least three are known to be present in Porto Rico. The others, root rot due to *Armillaria mellea*, a mushroom; Florida scaly bark, or nail head rust; brown rot, or Pythiacystis gummosis; and Botrytis or gray fungus gummosis do not, to the best of the writer's knowledge, occur here. Of the other three mal-di-gomma has already been dealt with, and an account will follow of the remaining two, psorosis or California scaly bark, and Diplodia gumming.

PSOROSIS OR SCALY BARK.

This disease, which is of considerable importance in Florida and California, is fortunately one which causes little concern in Porto Rico. In its characteristic form it is primarily a disease of the orange, and has been found in a few groves only. In as much as orange growing, as far as the cultivated groves are concerned, is decreasing little fear need be entertained of this disease ever becoming serious. It must not be confused with the nailhead rust, or scaly bark disease of Florida, which while very similar in outward respects, is due to a specific fungus, and attacks the fruit in addition. For this reason

[1] Cal. Agric. Exp. Sta. Bul. 262. See Bibliography.

the terms psorosis or California scaly bark are to be preferred to simply scaly bark for the Porto Rican disease.

The trunk and large limbs are the principal areas attacked, although in very severe cases the smaller branches and even the twigs will be affected. The disease is marked by the scaling off in flakes of the outer bark, a characteristic which accounts for the name of the disease. These diseased areas commence as small spots, often a fraction of an inch in diameter only, on the trunks or larger limbs. They increase slowly in size, ultimately coalescing to involve areas often several feet in length, and more or less completely girdling the trunk or branch. Some gumming accompanies the scaling off of the bark, but is more marked as gum pockets in the affected bark tissues than as an exudation on the surface.

FIG. 3.—Psorosis, or scaly bark. On branch of orange.

New bark, irregular and much roughened, forms beneath the dead bark patches, so that very soon the ulcerated areas, due to a succession of healing and breaking out anew and so characteristic of the disease, appear. Ultimately, in the larger areas the bark dies through to the wood, and the resulting open wounds are soon infected by various wood-rotting fungi.

Affected trees after some time, often several years, begin to show signs of unthriftiness by a yellowing of leaves and the presence of dead wood. Limbs here and there are completely girdled and die, destroying the symmetry of the tree. Death of the entire tree, however, is generally long delayed, and it may linger on as long as ten years, bearing more or less fruit each season.

Cause.

No cause has ever been found. Certain fungi have been noted at times in connection with disease lesions—for example, the *Corticium* of pink disease—but there is no evidence that there was any causal relation. The malady is held by most workers to be due to

non-parasitic influences, in particular to irregular water supply, or other environmental factors. It has not been apparent, as far as local conditions are concerned, that the nature of the soil, cultural practices, or temperature changes have any relation to the disease.

Control.

There is but one possible course of action against scaly back. Where a tree is very seriously attacked its removal is advised. A young, healthy tree in its place will soon more than make up for the diminishing returns obtained from a scaly bark tree. As far as observations show there is no danger of re-infection in replanting. Where only small lesions occur, or where they are limited to one or a few limbs tree surgery can be called into action. Diseased branches can be removed, and areas on trunk and main limbs cut out, as described under foot-rot. All precautions in the way of sterile instruments, clean cuts, thoroughness in removal of affected tissues, and final treatment of the wound are most advisable. The usual reason for failure in this line of work is neglect to cut deep enough, or far enough out around each lesion. Scraping off the dead scaly bark is not sufficient; the affected bark must be removed to the wood.

Where this disease is present, regular inspections should be made several times a year, followed by prompt treatment of all lesions found. A system of tree numbering as recommended will aid in keeping track of affected trees.

GRAPEFRUIT GUMMOSIS.

A type of disease very similar to psorosis appears to a limited extent on the grapefruit, and is in fact by some workers considered identical. This supposition is borne out by the observation that where grapefruit and orange trees occur in the same block of trees and are diseased, the oranges exhibit typical psorosis symtoms, the grapefruit the somewhat different gummosis signs. Again this form of disease cannot be clearly differentiated from foot-rot, the two grading into each other, so that a line can be drawn only by calling one a disease of the roots and crown, and the other a disease of the trunk and limbs.

Generally speaking, this type of disease can be distinguished from psorosis by the more copious gumming, the fact that it is limited to

the trunk and large limbs, and because the bark is more quickly killed down to the wood, so that open wounds or cankers, through which wood rot infection can occur, are formed early in the progress of the disease. The scaling of the bark so typical of the first form is much less marked in this, often almost completely absent. Nor does the disease enter into any long chronic state as does the other, but is more apt to be thrown off by the tree, or to complete its course within a comparatively short time by girdling.

As with psorosis the cause is unknown, although observations point to a parasitic origin. Various fungi are commonly encountered in the gumming areas, but neither local studies nor the very extensive tests carried out in Florida have definitely connected any fungus with the disease.

Control.

If taken in time very effective control can be had by the methods outlined under psorosis. The same precautions are necessary.

DIPLODIA CANKER AND DIEBACK.

While little loss, except in one or two groves, has as yet been occasioned by this disease it may easily become most alarming. The writer regards it as the most threatening of all bark diseases. The trunk, branches, and even the twigs are subject to attack. Infection may take place at any point as manifested by gum exudate and browning of the inner bark. Infected bark finally becomes black and dries out. The wood beneath is also attacked, and in the case of the branches penetration in this manner may be complete. The infection may spread over very extensive areas, involving entire limbs and sufficient of the trunk to cause death. There is practically none of the scaling off of the outer bark noted in psorosis, but merely the death of the bark, with more or less gum flow from cracks and open lesions.

This form of disease is due to the work of a common fungus *Diplodia natalensis*. The fruiting bodies appear in great numbers on the surface of the dead bark, as small black carbonaceous, slightly roughened, hemispherical to flattened pycnidia, within which are borne the reproductive bodies or conidia. These latter are distributed by wind, water, and probably insects, as well as by various instruments employed in grove work.

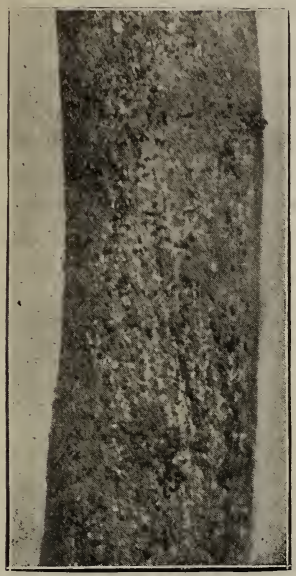

FIG. 4.—Diplodia canker. Showing black fruiting bodies of the fungus on dead grapefruit branch.

In attacking the twigs, *Diplodia* produces symptoms very similar to those of withertip, and in fact the injury caused has been called *Diplodia* withertip, or dieback. There is usually a slight production of gum to distinguish this malady from true withertip. In cases where this is not produced the disease may spread back into the larger limbs, or even the trunk, the gum apparently serving to check the growth of the fungus. The presence in advanced stages of the very characteristic fruiting bodies also helps to distinguish it from *Colletotrichum*. The latter, however, will also generally be present. In addition to the control measures outlined below, the general discussion under withertip will be applicable.

FIG. 5. — Diplodia dieback. Note the sharp transition between dead and living tissues.

Control.

Pruning of all diseased branches or twigs, and cutting out of lesions on the trunk, or main limbs will serve to control the malady if all precautions are taken. Exactly the same steps are necessary as have already been described for other bark diseases, but with

greater need for care, since a virulently parasitic fungus is present, and in great quantity. All prunings and other diseased material cut out should be destroyed, and all sanitary precautions observed.

Gumming will often occur where no specific disease is present, and is often due to mechanical injury, insect work, or other similar causes. Citrus trees form gum freely at any wound, apparently as a first step to healing, the gum being slightly antiseptic. In all such instances the wound should be thoroughly cleaned out and treated with a protective dressing, the cause being removed or corrected if present.

WOOD ROT.[1]

Some idea of the importance of this trouble may be gained when it is stated that there is not a grove on the Island which will not show some cases at least, and that there are groves in which practically every tree is infected. Instances have been seen where the disease had progressed so far that many trees were dead and the balance of a given block or grove in advanced stages of decay. Consequently there is no hesitancy in saying that this disease will play a most important part in grove decadence in the not very distant future. In fact, it is doing that at this very time, but the effects when considered at all have been referred to other causes, and it has been but seldom that any steps have been taken to prevent or control the trouble.

Characteristics and causes.

Wood rot is here used as a general term to cover a rot or decay of the wood of the trunk and larger branches, caused by a number of different fungi; for while several different types of rot may be distinguished, it is sufficient from the practical view point of control or prevention to consider them as one.

This disease has been well characterized as insidious. A tree may be in an advanced stage of decay without there being any surface evidences visible, unless careful search is made. The damage often becomes apparent only after a storm or other agency has broken a limb or split the trunk, exposing the rotted interior.

Several quite distinct types of decay occur, in some instances of the sap wood or outer wood layer only. In this case the bark will as a general rule also be involved, resulting in large trunk or branch cankers. In this type the wood through the action of the attacking

[1] A partial reprint of Circular 10, Insular Experiment Station.

fungi becomes soft and crumbly, so that eventually cavities are produced, which increase slowly in size as the rot works into the tree. Decay of this sort should be, and in most cases is, readily apparent to the grower, so that steps may be taken to check its spread, or eliminate it entirely.

However, there is another type, one that is more prevalent and much more dangerous, because not so easily located. This is a rot of the heart or center of the trunk or branch. An entrance is gained through a wound and from this point the rot spreads slowly up and down the trunk, and eventually into the larger limbs. Once an entrance is effected, decay progresses slowly (often over a period of many years) though none the less certainly, until the tree is destroyed. Lateral progress is not as rapid as that along the main axis of the tree. Rot of this type is generally dark colored and not less firm than normal wood until an advanced stage, when it becomes soft and friable. Rotted wood is, however, always much weaker than normal or healthy wood, which permits breakage by heavy winds, and other destructive agencies.

In the former type (sap rot or rot of the outer wood layers and bark) there is, of course, direct harm to the tree in that the water- and food-conducting tissues are destroyed, and the normal life processes of the tree interfered with, to an extent depending upon the size of the diseased areas. This would vary from a slight weakening to death, where the tree was girdled. In the case of heart rot, while possibly no direct injury results since heart wood is composed of dead tissues and takes no part in the transport of food or raw material for the use of the tree, the way is paved, through its slow but persistent action, for a premature death of the tree by helping to bring about a general weakening, in which condition other harmful agencies can complete the work of destruction.

Wood rot of all kinds is produced not by the action of the weather or by exposure to moisture or the air (although these are important contributing factors), but by the work of certain fungi. Several at least are concerned, it being possible to distinguish the work of one from that of another. Certain ones rot the sap wood only, others the heart; some produce a light-colored rot, and others a dark colored type. However, since the treatment or prevention of all types is practically the same, there is no need of going into further details on this point.

Without exception the fungi under consideration gain entrance only when some other agency has made an opening—or that is to

say, a wound—and for this reason fungi of this kind are known as wound parasites. In the presence of moisture the spores germinate on the surface or preferably in the crevices of the wound, producing a threadlike structure which penetrates the wood, dividing and subdividing as it progresses, and ultimately forming a complete net (invisible to the eye) in the invaded areas. Penetration of the hard wood tissues is brought about by the action of certain digestive fluids secreted by these fungus threads, or hyphae as they are called.

After the growth of the fungus, and the accompanying breaking down of the wood, have progressed for a considerable length of time, often for many years, fruiting bodies are formed. These are always produced at some points where the decay has reached the surface, and take different forms with the various species involved. The more common of these are the familiar shelf or bracket fungi (*Polystictus* spp.). (See Fig. 6.)

FIG. 6.—*Polystictus pinsitus.* The fruiting bodies of one of the common wood-rotting fungi.

On the lower surface of each bracket or fruiting body will be found a layer of very small, cylindrical pores, in which are produced the spores. Each of these spores, and great numbers are produced in each pore, is capable of again starting wood rot when it reaches a suitable location. They are carried by wind, water, birds, and other agencies to fresh wounds. Another very common type (*Schizophyllum*) produces numerous gray, oyster-shell shaped fruiting bodies, hairy on the upper surface, and below in place of a layer of pores, producing a series of gills or lamellæ on which the spores are borne. (See Fig. 7.)

FIG. 7.—*Schizophyllum commune.* Fruiting bodies of the split gill mushroom, a very common wood-rotting fungus.

The manner in which infection occurs has already been suggested, but because of the importance of this point in connection with prevention, some details will be given. Under normal conditions, the outer bark presents an effective barrier to the entrance of rot, but as soon as this protective area has been broken, a way is opened for

infection. There are many means by which wounds may be produced, including those caused by mechanical agencies such as hoes, or other instruments or machines used in cultivation, animals, and sunburn. Injuries from these sources are commonly taken care of, but those resulting from the attacks of parasitic fungi are but seldom given proper attention. Foot-rot gives excellent opportunities for the entrance of wood-rot, and similar results follow attack by the pink disease (*Corticium salmonicolor*), psorosis, Diplodia branch and trunk cankers, and other trunk diseases.

A third source of wounds occurs as a result of routine pruning operations. Faulty or careless work, the leaving of stubs which delay or prevent healing, combined with improper treatment, or none at all, make this class of wounds the most common point of entrance for decay.

As a general rule the rebudding or topworking of citrus trees in Porto Rico has not been successful, and there can be but little doubt but that wood rot, following sunburn of unprotected branches and trunks, and untreated or poorly treated pruning wounds, will explain in large measure the poor results obtained here from a system so successfully carried out in other citrus regions.

Treatment and prevention.

Under the head of treatment, little need be said. For while it is quite possible to apply the usual methods of the tree surgeon to infected trees, it is not advisable from a practical standpoint under Porto Rican conditions. The expense of cutting out diseased wood, filling cavities, putting in braces, and caring for other details would be prohibitive. Treatment is advised only in incipient cases, or where the entire diseased area can be readily reached. This will practically apply only to sap-wood or bark-rot. A word of caution is necessary with regard to attempts at treatment. The removal of part of the rotted wood only, the part that can be reached readily, for instance, and the scaling over of the wound will prove of no avail, but on the contrary will permit the decay to progress more rapidly than otherwise, since the wound can not dry out. Moisture is a requisite for decay.

It is recommended as a practical and economic measure that trees badly diseased or unthrifty because of wood rot, or any other cause for that matter, be dug up and replaced with healthy trees from the nursery.

It is to prevention that most attention must be given. Simply

stated, this consists of preventing wounds in so far as possible, and of the proper treatment of those that do occur, in order to prevent infection by wood-destroying fungi.

Mechanical wounds due to cultivation instruments, animals, or other agencies should be prepared for treatment by having all projecting stubs, loose bark and ragged edges of bark and wood cut off or smoothed down so that healing over by growth of new bark tissues can proceed as easily and as rapidly as possible. The wound itself may be treated according to recommendations given in latter paragraphs.

In those cases where foot-rot, pink disease, psorosis, or other primary diseases are the causal agents more care is necessary. Diseased branches should be removed by cutting well back to a healthy limb, or to the trunk itself. Cankers on branches and trunk due to specific diseases must be carefully worked over to remove every trace of diseased tissue. This involves removing not only the discolored bark, but the diseased wood beneath as well. As a precautionary measure cutting out should extend well into healthy bark and wood, a half inch at least. All diseased material removed should be buried deeply or preferably burned. A piece of sacking laid around the tree will serve to catch small fragments as they are cut away from the tree.

In ordinary pruning operations for the removal of dead wood and the shaping of the tree, certain precautions should be observed. In so far as possible branches which threaten at some time to interfere with others or to spoil the symmetry of the tree should be removed. Superfluous limbs should be removed at as early a stage as possible to avoid large wounds, and other difficulties attendant upon their removal. Most important of all is the necessity of close, clean cuts. The careless habit of leaving stubs of various lengths, even if only an inch or less in length, is responsible for a large percentage of wood rot. To avoid splitting, the precaution should be taken of removing large branches in two pieces, the first cut made a foot or so above the base of the branch to be removed, and then the second, final, careful cut, at the point of union with limb or trunk.

Where there is any tendency to bleed, further treatment of wounds should be postponed until the surface is dry. With citrus, however, this is rarely necessary. In the case of wounds resulting from foot-rot, Diplodia canker or other diseases, the next step after cleaning out all diseased tissues and making the edges smooth to permit of

rapid healing, is sterilization of the surface to kill any spores which may be present. For this purpose either corrosive sublimate or Bordeaux paste may be used.

These substances, it must be understood, are not permanent in their effect, and must be shortly followed by a permanent wound dressing. In the case of pruning wounds, or those produced by causes other than fungi, the first application of a disinfectant is not usually necessary.

There is not at present available an ideal wound dressing, but several which are in general use, or which are recommended for use, will be mentioned.

The substance most commonly used in Porto Rico for this purpose is Carbolineum Avenarius, a propietary compound. Because, however, of the difficulty of making sure of obtaining the genuine article (other types of carbolinium being, so far as known, injurious), and the unsatisfactory features of the substance itself, its use is not recommended. It is quite possible for injury to follow its use: in fact, such cases have been reported.

Common white lead or white-lead paints are also in common use. These are far from satisfactory, although of some value if the precautions given in a following paragraph are adhered to. There have also been used to some extent various propietary wound dressings. These are fairly satisfactory but their use should be preceded by the use of a disinfectant in all cases.

Of all the many substances at present available for this purpose in Porto Rico, gas tar stands first. This is a product of the destructive distillation of coal in making gas, and can be obtained locally at a relatively small cost, an important point in its favor. Gas tar is given second rank by tree surgeons and others who have studied the question of wound dressings. Certain asphaltum compounds are considered best, but are not available here. The tar has been under trial at the Experiment Station with most satisfactory results, which fact, combined with field observations in groves where it has been used and the general favorable reports given it by experts in the North, leads us to recommend it alone for this purpose. No cases of burning have been reported or observed. As a general rule the only treatment necessary is a good coating of gas tar carefully brushed on after the wound has been thoroughly cleaned and prepared. It will penetrate a short distance into the living bark, but no more tissue will be killed than dries out normally in untreated wounds.

Finally, there must be considered the renewal of the dressings.

for no dressing, no matter how carefully applied, will be permanent. In fact, the usual method of covering the wound with paint or carbolineum and then considering the matter finished, often results much worse than if no care were given at all. This is because of the cheeking or formation of cracks in all wounds of any size, no matter how well they may have been covered originally. Such cracks provide ideal lodging places for spores, and subsequent infection by rot. This will explain why it has been the experience of some growers that more wood rot apparently worked in through treated than through untreated wounds.

The method of procedure to be followed to overcome this difficulty is simple. At the time the pruners go through the grove all old wounds should be re-inspected, and any showing cracks or other evidence of unprotected wood should be given another coating of gas tar, or whatever other material is in use for the purpose. Large wounds will in this manner often require an annual coating for a number of years.

PINK DISEASE (*Corticium salmonicolor*).

One of the striking diseases of the bark is the so-called pink disease, due to a fungus technically known as *Corticium salmonicolor*. In other parts of the world, Java and Ceylon in particular, this is a most serious disease, attacking a large number of economic plants, and much attention has been directed to it. Among the many hosts reported have been *Citrus* spp. rubber (*Hevea* and *Castilloa*), tea, coffee, chinchona, cocao, nutmeg, pepper, coca, gandul or pigeon pea, mango, and cinnamon.

In Porto Rico this disease has been found so far on but two hosts, the grape fruit and sweet orange, and in isolated instances only. It is very probable that at least the gandul (*Cajanus indicus*) is also attacked, since it is so widely planted in citrus groves, but no certain cases have yet been found.

The first report was received during a very wet period of weather in the fall of 1915, and additional cases have been found from time to time since. There are no indications that the disease will ever become serious. The absence of large tracts of woodland, in which the disease could vegetate during dry periods, will probably explain in large measure the failure of this potentially serious disease to assume alarming proportions here.

In such instances as it has been found, it has been present on

trees in low or very sheltered places, indicating that it is dependent upon humid conditions. In no case has an entire tree been killed, attack having been limited to one or at most several branches only. The disease very often begins at the base of a limb, or at a point where several originate, probably due to the accumulation of moisture at these points, permitting the germinating spores to gain an entrance. Once established the spread of the fungus is quite rapid along the limb. If very moist conditions prevail, the limb may be speedily girdled, but more frequently one side only (that which is most shaded) is attacked.

The presence of the thin, bright pink, fruiting layer of the fungus is striking, so much so that this disease could not be confused with any other. The pink area with its narrow white margin often reaches an extent of several feet, advancing with the rot of the bark produced by the vegetative portion of the fungus, and even at times growing out over the sound bark in advance of the root. Not only is there a soft rot of the bark with a characteristic odor, but the wood beneath is attacked as well, resulting in its drying out, and becoming discolored. Various insects, particularly wood borers, soon appear in the wounds, as do also various saprophytic and wood-rotting fungi.

FIG. 8.—*Corticium salmonicolor*. Illustrating the fruiting layer of the fungus causing "pink disease." Note the normal twig on the uninjured side of the branch.

The fruiting layer, at first a bright salmon pink, fades with age to a dull gray or dirty white. It also cracks into small irregularly, rectangular pieces, giving the characteristic appearance which has resulted in its having been sometimes called the "writing fungus," the fragments being thought to resemble hieroglyphics (Petch). Reproduction is brought about by spores developed in immense numbers on the pink areas and spread by wind, insects, and rain. Although acting in some cases as a wound parasite, it is quite capable in the presence of some moisture of penetrating otherwise uninjured bark.

Control.

The absence of any extensive infections makes unnecessary such drastic measures as painting the trunk or limbs with Bordeaux mixture. Very effective control is possible by prompt removal of all diseased limbs, making sure to cut well back of any infected areas. All wounds should be immediately treated with gas tar or other wound dressing. If taken in time areas on the trunk or main limbs can be cut as described for gummosis, observing all precautions.

It is desirable that attention be given to the possibility of its occurrence on the gandul, or other plants in and about the grove. Any such plants which come under suspicion should be destroyed.

DIEBACK OR EXANTHEMA.

Dieback or exanthema, a common disease in Florida and to a less extent in other citrus-growing regions, is of very limited occurrence in Porto Rico. In fact in but one instance has it been found to be present to a serious extent. This was in a block of orange trees, several of which were already dead, and others dying or in advanced stages of the disease.

The symptoms of true dieback are very distinct and have been worked out in detail by Swingle and Webber. Briefly they are as follows: Growing shoots turn yellow and become stained reddish-brown, finally dying back. On new unhardened growth distinct swellings, due to an accumulation of gum, appear. In serious cases the bark on both old and new twigs, and even the smaller branches, bursts and reddish-brown stained, corky ridges form. Young shoots very often droop in a striking manner, described as S-shaped. One of the most marked signs is the production of multiple buds in the axils of the leaves on young twigs. This results in a bushy terminal growth, most of which finally dies back. Many of the larger limbs eventually succumbing, a crop of water sprouts is produced from the lower part of the tree, giving a most ragged appearance. The foliage is said to take on a deep green color, although individual leaves sometimes show stained areas. The fruit loses its deep green color, and there is a tendency to split. Brown irregular stains appear on the surface as well as gum exudations, and a large percentage falls. Finally there is present an infiltration of gum in the angles of the segments at the center of many of the fruit.

It is only rarely in Porto Rico that any number of these symptoms are found together. Multiple buds and dieback are common enough,

but the additional signs are usually absent. Exanthema is not to be considered of any importance at present.

The cause of the disease is problematical, but it is usually considered to be a mal-nutritional disease, due to an excess of nitrogen supplied in barnyard manure or other organic form. Poor drainage is also thought to be a factor. Instances have, however, been noted in Porto Rico where trees located near stables or heavily manured were in the best of health, and on the other hand trees which had received no organic applications whatsoever showed dieback symptoms.

The disease is generally controlled by stopping for a time all cultivation and using mineral fertilizers only. Many growers have claimed that the disease could be cured by the use of blue stone (copper sulphate) applied to the soil around affected trees, and this idea has been apparently verified by experiments carried out in Florida by the United States Department of Agriculture. It was found that from four to eight pounds of copper sulphate in two applications gave most excellent results in restoring to normal condition even very sick trees.

WITHERTIP, ANTHRACNOSE (*Colletotrichum gloeosporioides*).

The withertip or anthracnose fungus is one of the most common, if not the commonest fungus, in and about citrus groves. Very extensive studies have been made of the fungus and the several phases of disease caused by it. It is one of the forms universally distributed in all citrus-growing districts, and if the view of some workers is accepted, it is also the cause of important diseases of apple, guava, mango, avocado, and a wide range of other economic plants. At least all varieties of citrus are very subject to attack by it. Of late years there has been a tendency to consider it more in the nature of a saprophyte or weak wound parasite, than the virulent parasite it has so often been pictured. It is true that it is of universal occurrence on dead and dying twigs, and in leaf spots. In fact, citrus leaves and twigs, to all outward appearances normal, will almost invariably develope the fungus, when externally sterilized and placed in sterile damp chambers.

On the other hand cases have been observed where death of branches, or spots on leaves or fruit were quite clearly due to the initial action of this fungus. As a result of observations and studies to date, it is believed that under Porto Rican conditions the fungus

is ordinarily a saprophyte or weak wound parasite, except in certain instances as will be noted hereafter.

Leaf spots.

On the leaves the spots produced are medium to deep brown, finally gray, in color with definite margins, circular to irregular in shape, and up to an inch and often more in diameter, even at times involving the entire leaf. The spots commonly have a characteristic zoned appearance, due to the production of the numerous, minute, fruiting pustules in concentric lines. The appearance of the spots is practically the same on both surfaces of the leaf. Repro-

FIG. 9.—Anthracnose spots on leaves of lemon seedlings.

duction is brought about by means of the minute spores produced in great numbers in the sporodochia or fruiting pustules.

In a great majority of cases anthracnose leaf spots will be found in connection with scale infestations, they being particularly abundant on old leaves infested by purple scale. They are also commonly found on leaves partly consumed by biting insects, infection having occurred along the injured margins. Occasionally in contrast to this type of occurrence, cases will be found where no other initial injury is present. In one instance a large grapefruit tree was noted, apparently normal, except that a large percentage of the leaves was badly affected with anthracnose spots.

A much more virulent condition commonly exists among lemon seedlings in the nurseries. Here the spotting occurs in connection with scab, and not uncommonly reaches such proportions as to cause complete defoliation, with a resulting setback to the young trees. Except for their greater extent, and tendency to irregularity, the spots do not differ from those on other host species. The fungus involved is apparently *Colletotrichum gloeosporioides*, although careful cultural studies may reveal it as another species, as has been the case with the anthracnose of limes in Florida and California, or at least as a distinct variety.

A distinct type of leaf spotting, but probably due to the same fungus, has been observed in several newly set groves. After a season practically all traces of this form have disappeared. On the older and lower leaves, small deep-brown spots occurred, few to many, nearly circular, from two to seven or eight millimeters in diameter, and with slightly raised, very definite red-brown margins. It is thought that these spots were due to infection in the nurseries from the overabundant fungus material present there, but that the trees once they were removed to clean surroundings were able to resist, and finally eliminate the fungus.

Anthracnose of the fruit.

On the fruit typical anthracnose spots are produced. These are deep brown in color, generally sunken, and vary in size from minute points to areas several inches across. Any part of the fruit may be attacked. It is seldom that more than isolated cases will be found in a given tree, and most of these can be traced to some initial cause, a bruise, insect bite, or similar injury. Trees suffering from root rot, foot-rot, or other disease seriously impairing their health, show a large percentage of anthracnosed fruit. Fruit become more susceptible with maturity.

Surface infection, known as tear staining, is considered elsewhere, as is also the phase in which complete rotting occurs.

Withertip.

The most serious damage inflicted by this fungus results from attacks on twigs and branches, although here again it is difficult to say how much of the loss is really to be charged to this fungus, and how much to other agencies affecting the general health of the tree.

In the virulent form there is a sudden withering of terminal twigs, the leaves drop, and the wood dies back for varying distances.

In some cases branches of considerable size are involved, and more rarely even the major portion of a tree. The presence of the disease in this case will be very evident, the dead limbs standing out clearly from the normal portion of the tree. Affected trees show numerous dead twigs, a yellowing and shedding of leaves, and a general unthrifty appearance.

It is often difficult, in fact impossible, unless observed in the initial stages, to determine whether the death of the twig is due to actual attack by the withertip fungus, or whether some one of the many other causes which accomplish the same result has been operative, and the fungus merely a follower. A citrus tree tends to produce more wood than can be cared for, so that there is a constant natural pruning going on. Branches whose leaves fail to receive sufficient light to enable them to produce the necessary food supply, die, as well as those which because of their position, fail to receive sufficient water. In mose instances the wither-tip fungus, as well as various other fungi, will be found fruiting on wood of this kind.

Much of the actual disease of this nature that occurs is due to attacks of other fungi, or to the combined attack of one of them and *Colletotrichum*. *Diplodia*, of which more detailed mention is made elsewhere, is common in such situations.

Control.

Preventive measure are primarily recommended, since the presence or absence of the disease is so directly dependent upon the state of health of the tree, which is in turn influenced by cultural methods under the control of the grower. The most important factors are cultivation and fertilization. When these are given proper attention, the tree will of itself be able to throw off the disease to a large extent. The use of an excess of nitrogen, either as nitrate of soda or in organic form, is to be avoided, since such a practice tends to produce succulent growth with little resistance. A balanced fertilizer (as nearly as the times warrant), which will give a normal healthy growth, is recommended.

Where the disease has actually gained a foothold and some corrective measure seems necessary, a thorough pruning out of all dead or weak wood is desirable, combined with such corrective steps as are possible. Pruning, if carefully done and reinforced with proper sanitary and cultural steps, will keep the disease in check. Spraying with Bordeaux has often been recommended, but this will seldom if ever be advisable under Porto Rican conditions.

MISTLETOE (*Dendropemon* spp.).

Parasites belonging to this group occur in a number of localities, particularly in the western part of the citrus district. The plants may be present as isolated specimens only, or at times may be so abundant as to cause considerable injury to the host tree. Mistletoe is a true flowering plant in contrast to the other parasites of citrus, which are fungi. It reproduces by means of seed enclosed in a sticky pulp, which causes them to adhere firmly to a branch or other object with which they come in contact. Birds are very efficient carriers, and are largely responsible for the spread of the parasite.

The seeds germinate and send root-like processes into the tissues of the host, erect shrubby plants developing. Possessed of green leaves, the mistletoe to a considerable extent manufactures its own food supply, but draws entirely, of course upon the host for raw materials, water and dissolved mineral salts. The limbs attacked die beyond the point of entrance of the parasite, the water supply being diverted to the latter. This results in an unsightly appearance, as well as a reduction in the bearing surface of the tree.

At least two species are found on citrus (orange and grapefruit) *Dendropemon bicolor* and *D. caribaeum*, both of which also occur on a considerable range of other hosts, some of economic importance.

As a control measure, the pruning out of infested limbs is feasible, together with similar action in neighboring non-citrus host trees, or even the removal of the latter if they are of no particular value, or heavily infested.

SCAB.[1]

Of the various diseases of grapefruit in Porto Rico, citrus scab, or lemon scab, has beyond much doubt assumed a position of first rank, and has been one of the chief agents in sending fruit to the cull pile and in the lowering of grades. During the past four or possibly five seasons—the time in which the disease has been especially virulent—it has been not at all uncommon in certain districts for the larger part of the crop of a number of groves to be so disfigured as to be worthless, representing a total loss on the season's work.

This has been especially true in those seasons when low prices have made it impracticable to ship anything but the highest quality of fruit. It would be extremely difficult to give any estimate of the losses that have been sustained, but they will reach a total of

[1] Abridged from Bulletin 17, Insular Experiment Station.

many thousands of dollars, including not only that caused by the immense quantity of fruit consigned to the cull pile, but that which comes from placing in the lower grades all that is disfigured by the disease.

Citrus scab is an introduced disease, which has been present many years, probably having been introduced originally from Florida. It first appeared on the sour orange and lemon, particularly on the seedlings of these varieties in nurseries, but as they were of no economic importance or were soon budded over to the immune orange or grapefruit, no attention was paid to the disease.

This was the status of affairs until the excessively wet season of 1911–12, when the grapefruit was attacked suddenly, and in the most severe fashion in the Bayamón section. Since that date there has been no decrease in virulence, and furthermore most of the other citrus districts have been invaded in turn.

Varieties attacked.

As has been noted above the sour orange (*Citrus aurantium*), and the rough lemon (*Citrus limonia* var.) have always been especially subject to attack, it being quite usual for one hundred per cent of seedlings in the nursery beds to be badly distorted and stunted. The other varieties of the lemon according to reports, were equally diseased at the time when they were grown in commercial groves here.

Shoots from the lemon roots of grapefruit trees are very subject to scab attack.

The lime (*Citrus aurantifolia*), the satsuma, and the mandarin (*Citrus nobilis* var.) have not been noted as susceptible in Porto Rico. The king orange (*Citrus nobilis* var.) is attacked, but not seriously. The kumquat (*Citrus japonica*) is free of the disease in so far as known.

The sweet orange (*Citrus sinensis*) is usually considered as immune, but in several instances trees have been found bearing a few scabby fruit, generally when in close proximity to diseased sour-orange trees. It is, however, considered not at all unlikely that it may lose this immunity at any time, as has but recently happened in the case of the grapefruit.

Of the grapefruit (*Citrus decumana*), three principal types are grown in Porto Rico on a commercial scale, the Duncan, the Marsh's seedless and the Triumph. The latter has at all times been immune, with the exception of slight infections found on seedlings. Because

of its poor shipping qualities and other commercial defects, further extensions of the planting of this variety are out of the question, even though its use would eliminate the scab.

The two other varieties are both very subject to the disease, no difference in their relative susceptibilities having been found, although, in the opinion of some growers, the Marsh is less severely attacked than the Duncan. Such differences as do occur from grove to grove can be readily accounted for, it is thought, by environmental or other local conditions.

It has been stated [1] that certain non-citrus plants, the gandul (*Cajanus indicus*) in particular, are subject to the same disease or one not distinguishable from it. No evidence was given to support this theory, nor has any developed since, and it is not believed that any fears need be entertained that the disease is present on plants other than citrus.

Appearance of the disease.

Citrus scab attacks the fruit, leaves, and young twigs. The

FIG. 10.—Citrus scab on young grapefruit.

first signs of infection are circular, minute, translucent areas, fol-

[1] Report Agricultural Experiment Station, Mayagüez, 1911.

lowed by a rapid production of the corky outgrowths so characteristic of the disease. On the fruit these corky outgrowths, wartlike in appearance, vary much in size and shape, often running together, or occurring in such numbers as to cover a large percentage of the surface of the infected fruit. At times plateau-shaped areas are produced, of an inch or more in diameter, irregular in shape, and marked by the dying of the epidermis and its breaking up into silvery scales. Again it may take the form of ridges, conical elevations, or other shapes.

The corky areas are dull brown in color in some instances, but very commonly are a dull red with brown margins. This latter stage occurs where the disease is especially virulent, the ridge and plateau condition being more often noted in instances where but little disease is present. This latter is the type found on oranges.

Fig. 11.—Citrus scab on full-grown lemon.

Fig. 12.—Young grapefruit deformed by citrus scab.

Young fruit are frequently much distorted, assuming triangular or other peculiar shapes. Those most distorted fall to the ground soon after attack. It may be noted that a larger percentage of scabbed fruit fall than of normal ones. Infected fruit remaining tend to regain their normal shape by subsequent growth, and as there is no increase in size of the initial infections, the great increase of the surface areas of the fruit gives all appearance of a partial recovery or "cleaning up" from the disease. This, of course, is not what takes place, but merely means that there has been no further spread of the scab areas.

Leaves are frequently distorted, the same corky areas appear-

ing on them as on the fruit. Where infection is not general, very marked conical projections, often as much as a centimeter in height, appear. (Fig. 14.)

Fig. 13.—Citrus scab on lemon leaves.

The diseased areas are surface infections only, there being practically no penetration in either leaves or fruit of the inner host tissues. In fact so effectively are the inner tissues protected that scabbed fruits are no more subject to decay than normal ones.

Fig. 14. — Characteristic conical projection caused by citrus scab on grapefruit leaf.

Cause.

The disease is produced by the action of a parasitic organism. This spreads from place to place by means of exceedingly minute spores or spore-like bodies. Many workers have confused, in this connection, certain fungi with the casual organism, so that further work is necessary to properly place and name botanically the latter.

It is quite common to find one or more fungi in and about scab areas which are, however, merely secondary. The scab organism is not visible at any time to the unaided eye, either as a black mold or otherwise.

The reproductive bodies of the disease are carried in different ways by rain and dew, by wind, and quite probably by insects, and other agencies. Most of the mischief is accomplished by the first two, one affording a ready means of spread through any given tree, and the other accounting for the spread from tree to tree as well. The presence of the disease in each of the many infected groves can generally be accounted for by its having been present on the young trees, when they were brought in from the nursery for planting.

In the presence of sufficient moisture on the young unfolding leaves or newly formed fruit, the spore washed down from an infected leaf or fruit above, or blown in by the wind, begins its development by sending a delicate thread-like structure into the tissues of the host. As this growth continues, the plant reacts to produce the characteristic corky outgrowths, which represent its efforts to throw off the disease. It is successful in this to the extent that the disease never penetrates to any great depth, nor continues to develope any great length of time. The organism, however, remains alive in the corky lesions, and is capable whenever conditions are right (a period of wet weather) of producing a new crop of reproductive bodies. It appears to hold over to a greater extent in the leaves than in the fruit.

Contributing factors.

Scab attacks only the very young growth, so that the critical period during which infection is possible is quite short. In the case of the leaves, this period includes the time from the first breaking of the bud (when the leaves first show as green points) until the leaves are full size. Most of the infection occurs while they are from a quarter to a half an inch long and while the two halves are still folded together. Infections at this time cause distortion or the broad scabby patches over large portions of the surface, while later infections occur as isolated points only and the leaf remains normal in shape. New shoots coming out from old infected ones are peculiarly subject to attack.

The small fruit are susceptible from about the time of the fall of the petals, possibly before, until they are about an inch in diameter. Infection is especially apt to take place where several fruits touch, or where one is partly covered by a leaf.

The most important factor influencing the prevalence of scab is the nature of the weather prevailing at the time the flush and bloom appear. For the initial growth of the disease, moisture in the form

of rain or dew on the young tissues is necessary to permit of the germination of the spores and the entrance of the organism into the tissues. The ordinary heavy dews of the Island are quite often sufficient to permit of this, but a period of wet, cloudy weather produces an especially favorable situation for a severe attack.

Except as a carrier of the infection, wind has an indirect influence only, in so far as it serves to dry up the moisture in the trees and so prevent infection. In this connection it has often been noted that low-lying blocks of trees, or those protected by hills or heavy windbreaks, are, other conditions being equal, most susceptible. In most groves scab has first appeared in just such situations. The elimination of windbreaks to check scab is not recommended, except possibly in isolated cases where they have been put in too close or have become too large.

In any block of trees the amount of scab may vary from year to year, and to a less extent from tree to tree. Observations make it quite clear, that this is due in large part to weather conditions at the time of blooming and for a short time thereafter. Wet, cloudy weather will ordinarily mean a heavy visitation of scab, while clear, sunny weather means that the fruit comes through comparatively clean. There are, of course, many exceptions to this rule. In those groves which the disease has not yet reached all fruit remains clear in spite of the weather prevailing. In those blocks of trees which have been subject to disease, some infection will occur no matter how bright and clear the weather may be. It has been often noted that there are in most groves a number of trees, often only one or two, that are peculiarly susceptible, and doubtless serve as infection centers from which the disease may spread rapidly when conditions become favorable.

Very often the presence or absence of the disease in the trees of a grove depends upon the time at which the bloom and flush appear, it being quite common for great variations to occur in each block of trees in this latter regard. For example, those trees that bloom during the first two weeks of February might escape the bulk of infection owing to dry weather, while trees in the same block and similar in all respects, except as to later blooming, might some weeks later be very severely attacked.

No evidence has been secured to indicate that the stock on which the grapefruit is budded, (rough lemon, sour orange, and of late years, grapefruit,) has any effect on the relative amount of the disease present.

Unlike many other plant diseases, citrus scab shows a decided preference for healthy, vigorous trees, and it has been generally observed that, other conditions being equal, the best-kept grove or the most thriving trees fall easiest prey. It is rare indeed to find trees suffering from foot-rot, dieback, or advanced cases of wood rot also attacked by scab. In the many abandoned plantings examined no traces of it have been found, even though the trees are well protected, and infected groves are close by.

It is not, however, recommended that there be any lessening in the cultivation and fertilization of the grove in an attempt to control scab.

Control.

During the years when the grapefruit was free of the disease no steps were taken to check it beyond the budding over of the seedlings in the nursery as speedily as possible. No care was taken in setting out young trees to free them of what little scabby growth might be present. As this state of affairs occurred in practically every grove, it is not surprising that the disease has been able to spread so rapidly, once the resistance of the grapefruit was destroyed. Since then great efforts have been made to control the disease, particularly by the use of various sprays.

One very vital fact, that has been largely overlooked, is that all measures must be preventive and that a "cure," once the disease has a hold, is impossible. Once penetration of the host tissues has been effected, any amount of spraying is without avail, other than to kill such slight surface growth as there may be, which is readily replaced from within, after the spray material has washed off. To be effective the fungicide applied must reach and kill the spore before it begins its growth. Hence for absolute protection it would be necessary to keep the surface of the leaves and fruit completely covered during the susceptible period.

Removal of infected sour-orange and lemon growth.

This is a step generally recommended and one that should be followed out most carefully. It will be desirable to destroy, not only any wild sour-orange trees that may be present on the *finca*, but to search for any that may be growing in the vicinity in waste land, windbreak lines, or other holdings, especially small native plantings. In the case of lemon trees, removal is advised if they show any considerable amount of scab; but if, as has been observed in several

cases, single trees are free of disease, nothing will be accomplished by their destruction. The same recommendation will apply to other types of citrus grown as isolated specimens for home use of the fruit, or for the seed—destroy only when they become diseased.

The destruction of the lemon or sour-orange root sprouts, so common and so generally scab infected, is, of course, very desirable. Similarly in the nurseries there should be no delay in getting rid of infected material, and as a further step at this point, the young budded trees should be given such pruning as is necessary to keep the disease in check, aided when needed by spraying.

Pruning.

Heretofore it has been customary for writers on this subject to advocate the pruning of diseased leaves and twigs, and the removal of scabby fruit as important points in control. Recent observations made in groves, where such steps have been taken, have made it appear that no particular good is accomplished, and that, at best, results sufficient to pay for the expense involved are not received. It appears that no matter how thoroughly scabby material is removed, reinfection occurs in a propitious season, and apparently with undiminished intensity. Moreover, there must be considered the effect on the trees of removing such a large proportion of the bearing surface as is often involved in work of this kind.

On a small scale—that is to say, in small isolated groves or blocks of trees, or in instances where but a very few trees are involved—pruning, if properly performed, can be made effective. All scabby growth must be removed, and the trees examined sufficiently often to keep out all such material. When it is realized, that a single scabby fruit or cluster of leaves left after pruning, will suffice to reinfect the tree and probably others adjoining as well, the necessity of great care in this work will be seen. It will also be clear that the limit of practicability in this regard (number of trees that can be handled) is soon reached.

It has been observed that scab often makes a beginning in a grove by infecting over a period of several years one or a few trees only, scattered about through the planting. After gaining sufficient headway in these susceptible trees, it spreads over the balance of the grove, often in a single season. When such instances have been found, the budding over of the trees, using buds from nearby, thrifty, scab-free trees, has been recommended. Such a course, it is thought, will in the long run prove more effective than a series of prunings.

As a preliminary to spraying and as an aid thereto, as much as possible should be done in the course of routine operations to remove all sources of infection; that is, the scabby leaves and fruits. As far as the fruit is concerned, this merely means the picking and shipping of it before the new bloom comes on, and need take no particular extra time or money outlay. With regard to the leaves it should be the aim to take them out, in so far as practicable in the course of ordinary pruning operations. It is quite certain that this work as a special operation will not pay, even if time could be found for it. The point to be remembered in this connection is that the more of the infected material removed, the less there will be required of the spray applications.

Spraying.

That scab can be controlled in a practicable manner, though not eliminated, is certain. Very satisfactory results have been obtained in Florida, and some growers here have had measurable success.

Practically only two materials have been used or considered as fungicides for scab control, Bordeaux mixture and sulphur, the latter generally as lime-sulphur. Tests carried out in Florida, as well as such limited work as has been possible here, have demonstrated that Bordeaux mixture, properly applied, has an efficiency of from eighty-five to ninety-five per cent, while lime sulphur reaches a point of approximately thirty-five to forty per cent only. The former has, however, proven very objectionable because of the great increase in the amount of scale following its use, due in large measure to the destruction of various beneficial fungi which occur in enormous quantities in all Porto Rican citrus groves. If not taken care of in time the scale will, after several Bordeaux applications, become so plentiful as to cause very severe damage, or even the death of many trees. It has also been suspected of having an injurious effect on citrus trees from a physiological standpoint, and is more than apt to burn the tips of a new flush.

Lime-sulphur has an opposite effect in so far as it produces results at all. At the strengths commonly used it destroys only very small amounts of scale, but on the other hand does not apparently affect injuriously the beneficial fungi. It is, of course, very efficient in destroying rust mites and red spider, in decided contrast to Bordeaux.

Sulphur or sulphur compounds in the form of dust have been

tried out during the season just past, and found wanting in so far as scab control was concerned.

The situation arises then of two available materials, one effective but injurious, the other only partially effective but otherwise desirable. An attempt to arrive at a satisfactory solution of this difficulty is given as part of the suggested spray program.

The great difficulty in deciding upon the time of spraying and the number of applications, lies in the fact that it is impossible to know just when the principal bloom period will occur, or how many secondary blooms will follow. A heavy flush and bloom may be expected any time after the first of the year, but may not come until March in some districts. Following this there is scattering bloom and new growth until late April when, between that period and the middle of June, a second heavy bloom generally occurs. Throughout the balance of the year scattering bloom may occur at any time; very often in August or the late fall months. New leaves, of course, are coming on at practically all times. This seasonal variation makes it practically impossible to lay down any set program, but rather an attempt must be made to outline a tentative scheme to cover all possibilities, leaving to each grower the task of fitting it to his own individual circumstances.

Bearing in mind that all young growth is susceptible, it would theoretically be necessary to spray throughout the year, an impossible course. Practically, the best that can be hoped for is to give a limited number of applications at such times as they will accomplish a maximum amount of good.

Where the scab does not threaten to become serious, lime-sulphur or other similar sulphur compounds should be used, the first application being given shortly before the first bloom and flush of the season begins to expand. This is to be followed by another as soon as the bloom is at its height. The third application will come from a week to ten days later. Other applications may follow at the same or much greater intervals of time, all depending upon the rate of progress of the bloom, the coming of secondary flushes, and above all upon the weather. Periods of bright, sunny weather will make spraying unnecessary; wet, cloudy weather will necessitate frequent, careful applications. These points must be decided by each grower for himself.

Some growers have adopted the system of spraying once a week through the bloom period, making a total of eleven or twelve applications. This is unnecessary; three or four at the proper time being

equally effective. The weekly program is, however, much to be preferred to none at all.

As to the strength of solution to use, 1 to 30 is that usually recommended. This strength is very effective for rust mite, but does not kill a very large percentage of scale insects, nor is it as efficient a scab preventive as is desired.

It is therefore recommended that a strength of at least 1 to 25 (concentrate at 32° B.) be used for the second and third applications. Further tests may even make it desirable to use a greater concentration than this, but care must be taken to prevent excessive injury to young growth. It would be advisable for each grower to conduct experiments of his own as to the strengths that can be used without burning.

The important thing to be remembered is to make thorough applications at the critical time, using the material as strong as is considered safe.

The preceding lime-sulphur program may well serve for many groves, but it is unfortunately true that there are others so severely disease-ridden as to require a more strenuous program. For these the Florida schedule is recommended. The first spraying may be, as before, of lime-sulphur (1 to 25) before the bloom appears, a sort of clean-up spray to remove old scabby leaves and help protect the new growtn. Then the second application is Bordeaux mixture (3–3–50) at the height of the bloom, followed within a week or ten days by another at the same strength or by strong lime-sulphur, depending upon the weather and other conditions. The first application, however, other things considered, should be all the Bordeaux given, except in very exceptional cases, though this again must be left in large part to the grower's discretion. One or more additional lime-sulphur sprays may be given, if necessary, at the usual intervals.

MELANOSE (*Phomopsis citri*).

Melanose, a serious disease in Florida, has been reported several times from Porto Rico, but it appears that for the most part these reports have been erroneous, or that true melanose has been confused with greasy spot, a phenomenon of universal occurrence. True melanose has been found in a few groves only, and even in these cases has been confined to one or at most a few trees only. The most characteristic example found was on a sweet-orange seedling, which was severely infected, together with one adjoining grapefruit tree partially overhung by the orange. It has been observed by Faw-

cett [1] that melanose is more serious in the more northerly citrus districts of Florida, decreasing to the south, and practically lacking in Cuba. For this reason it will probably never assume any importance in Porto Rico.

Melanose is a disease of the fruit, leaves, and young twigs. It is characterized by numerous, very small (seldom over one-sixteenth of an inch in diameter), raised corky areas, yellow to deep brown in color, and often described as having the appearance of masses of burnt sugar. These corky projections are superficial only, never penetrating the inner tissues of the organ attacked. They may be scattered irregularly, or in the case of the fruit, be arranged in lines or partial circles. They have the additional characteristic on the fruit of being encircled by a break in the epiderm, giving a scaly appearance. Melanose-affected fruits have a russeted appearance and feel rough to the touch.

FIG. 15.—Melanose markings on orange leaves.

Leaves and twigs are subject to attack only while very young and before they have hardened. The fruit is susceptible until practically mature.

Melanose is due to surface infection by the spores of a fungus known as *Phomopsis citri*. It develops in dead twigs, producing very minute, black, immersed fruiting bodies, and the spores are carried by rain or other agencies to the new growth. The melanose markings themselves contain very little fungus growth and never produce spores.

In Florida the same fungus causes a rot in the mature fruit, almost exactly similar in outward appearances to the stem-end rot of Porto Rico, but this phase has not been noted here.

The disease can be satisfactorily controlled under local conditions by pruning out all dead wood. If at any time the disease should become more serious, a spraying schedule can be outlined for holding it in check.

[1] Bul. 262, Cal. Ex. Sta.

BLACK MELANOSE OR GREASY SPOT.

This almost universally present spotting of the leaves is known to many of the growers as melanose, and hence much confusion has resulted. Greasy spot is a common disease in Cuba and the Isle of Pines, but is less prevalent in Florida. Grapefruit leaves are especially subject to it, although it can be found on practically any citrus species.

It is characterized by generally numerous, somewhat irregular areas, occurring on both leaf surfaces, but more prominently on the upper, and varying from an eighth to a quarter of an inch in diameter. The markings are only slightly raised, and vary in color from a light yellow or mere translucence of the tissues through various shades of brown to a very deep brown or black. In the younger stages there is a greasy appearance, suggesting the name. They can easily be distinguished from melanose markings by the larger size and the fact that they are very slightly, if any, raised.

Trees of all ages and in all conditions of health and disease are apparently subject to this phenomenon, and although no fungi or other organisms have been found associated with it, indications point rather decidedly to parasitic origin. Inasmuch as no appreciable damage is caused, affected leaves falling very little if any sooner than normal ones, control measures are not considered necessary.

STELLATE MELANOSE.

Certain peculiar markings, given the name of stellate melanose, have been found on grapefruit leaves, but never to such an extent as to be causing damage. These markings, which occur on either side of the leaf, though more commonly above, may be few or many, and in their raised character and color are similar to melanose markings. They are, however, much more extensive, often from four to eight millimeters across, and irregular to stellate in shape. An especial characteristic is the longitudinal splitting of the branches of the individual spots.

The cause is not known. It is interesting to note in this connection that this spotting has been found in but three groves, and in each case following Bordeaux spraying. Orange trees and unsprayed grapefruit in the same groves were free of the markings.

ALGAL LEAF SPOT (*Cephaleuros virescens*).

The lime is especially subject to this leaf spot, to such an extent, in fact, that it almost serves as a distinguishing characteristic

of the species. The other citrus types are also subject to it, but to a less extent, heavy infections having been noted only in the vicinity of lime trees. In addition to citrus, a very large number of other evergreen-leafed trees and shrubs serve as hosts, among them being the breadfruit, camphor, hibiscus, guayaba, nispero, and many ornamentals. Very little damage can be attributed to this disease beyond the slight reduction in leaf surface.

The nearly circular spots occur, for the most part, on the upper surface of the leaves, vary in number from a few only to many, and in size range from a few millimeters to nearly a centimeter. They are slightly raised, at least after the initial stages, and in color vary from dull red to brown, and finally become deep dull brown. On dead leaves they take on a grayish tinge. The leaf tissue beneath each spot is killed, showing on the under surface as a brown area, otherwise unchanged, and more or less the size of the spot above. At certain stages of growth, the surface of the spot shows a deep orange or red fuzzy appearance, due to the presence of a large number of short, erect hairlike processes, which bear the reproductive bodies at their tips.

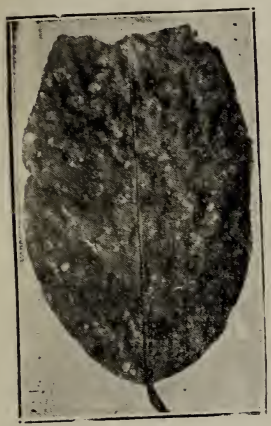

Fig. 16. — Algal leaf spot on lime leaf.

The parasitic organism involved is not a fungus, as with various of the other maladies with which we have been dealing, but an alga, a low type of plant related to the pond scums and sea weeds.

In addition to this form on the leaves, a type, very similar if not identical as far as the cause is concerned, occurs to a limited extent on the twigs and branches, particularly of sour orange and grapefruit, and is common on the gandul (*Cajanus indicus*). In this type the areas are irregular, several often coalescing and extending for considerable distances along the twig or branch. The fruiting stage has much the same appearance as in the leaf form. Some doubt is entertained as to the identity of the two forms, not only because of the slight differences in appearance, but because they have never been found in the same tree, or even in the same grove.

Corrective measures are hardly necessary, attacks on orange and grapefruit being so slight. It is probable that ordinary spraying

operations tend to keep it in check. The removal of affected, mature gandul plants will also doubtless aid in checking the twig type.

FRENCHING, MOTTLED LEAF.

The yellowing of leaves of orange and grapefruit trees is a very common phenomenon in Porto Rican groves, and may be due to any one of several causes. Various specific diseases, due to both fungi and unknown causes, are marked in part by a yellowing of the foliage, and this state of affairs is especially prevalent in abandoned blocks of trees, or those suffering from neglect. Trees which have borne a heavy crop of fruit will show considerable yellowing before the spring application of fertilizer is given, resuming normal color very quickly after this operation.

Yellowing of this nature is generally easily diagnosed and correctives can be applied, but there is a distinct type, commonly known as frenching or mottled leaf, the cause of which is obscure. In this case the leaves show irregular yellow spots, with definite margins, the background re-remaining green (Fig. 17.) Very often isolated trees only are subject to this spot, or a few limbs only in a given tree. Studies made in California seem to indicate that this trouble is due to a lack of humus in the soil, which is being supplied there by a system of mulching. The disease is hardly of sufficient importance to warrant any detailed attention here.

FIG. 17. — Frenching or mottled leaf of grapefruit.

Yellow spotting, a similar trouble of the leaves occurring in Florida, has not been noted here.

SOOTY MOLD.

The black, sooty layers of growth so commonly seen in the groves, and known to all as sooty mold, are fungus growths, but not of a parasitic nature. They live on the honey-dew or secretions of certain insects, in particular of the hemispherical and turtle-back scales and the wooly white fly.

No damage is caused, except through the cutting off of light from the food-manufacturing tissues of the tree by the black fungus layers growing superficially over fruit, leaves, and twigs. A variety of spore forms are produced, but whether they are of one species or several has not been definitely worked out.

Sooty mold can be eliminated by killing the scale or other insects, which it follows, by the use of oil emulsion or some other scalecide. Freedom from scale and hence from sooty mold, will eliminate in large part the necessity of washing the fruit, a procedure which increases the amount of rot.

FRUIT ROTS, OR SHIPPING ROTS.

The several fruit rots, or shipping rots as they are also known because of their developing during shipment, quite probably cause the greatest financial loss of any of the citrus diseases. They will even take first place over scab, since all rotted fruit is a dead loss, but much of that which is scabby can be sold in the lower grades. The amount of rot varies from season to season, depending upon moisture conditions, and other factors. The time of year, or in other words the maturity of the fruit, has an important bearing on the prevalence of rot, the percentage running high, as a rule, during the latter part of the shipping season, when much of the fruit is overmature. The actual loss will vary from one to fifty per cent of each shipment, possibly averaging five per cent for the season, wild oranges excepted, which have a much higher percentage. In estimating the loss, there must be taken into account not only the actual rot, but the lowering of price of the remaining sound fruit, the cost of repacking at New York, and the damage to the reputation of a brand showing heavy rot.

Several fungi are involved in the rotting, so that distinct types, stem-end rot, blue mold, anthracnose, and blossom-end rot are distinguished.

STEM-END ROT, DIPLODIA ROT.

This rot may attack the fruit at any time from partial maturity to delivery on the market. Certain groves or blocks of trees are much more subject to it than others, due in part at least to the greater abundance of the causal fungus on dead wood in the trees.

In a great majority of cases infection occurs at the stem end of the fruit, and hence the common name. A soft rot ensues, increasing very rapidly in extent until the entire fruit is involved. The rot works through the central pith portion of the fruit, appearing

at the blossom end by the time the softened area at the opposite end is an inch or two in diameter. Externally at this stage it appears as if infection had occurred at both poles of the fruit. The two areas rapidly coalesce. If attached to the tree at the time of infection, the fruit remains hanging but a short time only. Two or three days is ordinarily sufficient for the complete rotting of a fruit. Rotted areas at first show only a very slight change in color, but soon become light brown or tan, sometimes with black bands corresponding to the sections of the fruit. There may or may not be present an amber-colored juice exudate. After falling the fruit is rapidly consumed, shrinking, and ultimately becoming black and mummified. At this latter stage it will be covered with numerous minute, pimple-like projections, each of which represents a fruiting body of the causative fungus, *Diplodia natalensis*. The spores or conidia are produced in these pycnidia in enormous numbers. There is seldom any loss from this source of rot until the fruit is full grown, but from that period on, there is an increasing tendency to decay, particularly during periods of very wet weather.

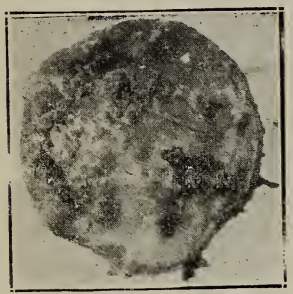

FIG. 18. — Portion of fruit rotted by *Diplodia* in damp chamber. Note the flocculent mycelial masses, each of which encloses a pycnidium or spore-producing sac.

In addition to this typical stem-end form, attack may take place at any point on the surface, particularly through insect punctures, bruises, or other injuries. Where one of a cluster of fruit is infected, the fungus, by working back into the fruiting twigs, attacks successively the others, killing back the branch as well for some distance. This is especially liable to occur where props are used, such a procedure apparently weakening the resistance of fruit and branch by cutting off the sap flow.

Rotting may occur at any time during the operations of picking, packing, and shipping, and under present conditions is very prevalent during the latter stage. Lack of refrigeration and the consequent high temperature and humidity make ideal conditions for excessive rot on shipboard.

Several types of soft rot are distinguished by those who handle the fruit in New York, principally based on the portion of the fruit first attacked and the presence or absence of the juice exudate, but all are due to the one fungus.

Control.

No one method will suffice to control or even to check this serious trouble, and it will only be by a judicious combination of the several points to be considered that any success will be obtained.

The first consideration should be given to a careful pruning out of all dead and dying wood, much of which under usual conditions harbors the fungus. A large proportion of the infection comes from this source. All precautions in disposal of prunings and treatment of wounds should be observed. In connection with this work all drops should be gathered up and buried, since, as already noted, they also serve as infection centers. Drops should be removed at frequent intervals.

The control of scale insects, particularly the purple and the chaff, has an important bearing on the problem, since scale-infested fruit are very liable to infection, particularly when the insects gather around the stem end. The puncture made into the fruit tissues affords the fungus a ready means of entrance. Scale insects are readily controlled by various spray compounds, Circular 9 of this Station treating of this phase of the problem.

Care in picking, packing, and shipping will aid in decreasing loss from this source. Since these points, however, more directly concern blue-mold decay, they are treated in detail under that heading.

BLUE MOLD.

Blue-mold decay was formerly more prevalent than at present, since control measures are better understood and are being practiced. This type of decay commences as a soft spot at any point on the surface of the fruit and spreads rapidly, two days being generally sufficient to bring about complete destruction. The affected area is soon covered by a thin white mold, which later turns blue-green or olive-green, the color being due to the layer of spores produced. If undisturbed an infected fruit becomes uniformly covered by the fruiting layer, giving off a dust-like cloud of spores if disturbed. Two fungi may produce this type of decay, *Penicillum italicum,* which is blue-green in the fruiting condition, and *Penicillum digitatum*, which is olive green. The first is marked by a narrow edge of white mycelium around the fruiting area, the whole fungus growth not covering the entire rotted surface; while with the latter species the opposite is true, a broad white mold layer advancing with the rot of the fruit.

Control.

The control of this decay is based upon the fact that uninjured fruit cannot be attacked by *Penicillium,* in contrast to *Diplodia* which is quite capable, some moisture being present, of attacking sound fruit. With the above fact in mind it will be clear that any and all of the points included under the phrase, careful handling, will be of importance in the operations of picking, packing, and shipping.

In picking, clippers with rounded points are necessary to prevent "clipper cuts," and fruit should be cut with as short stems as possible. To attain this result the stems are cut long at first, and then recut when the fruit is in the hand of the picker. Fruit should be placed carefully in the picking sack or basket, not thrown or dropped. There should be no sharp edges, broken slats, or protruding nails in the field crates. Considerable care is necessary in manipulating ladders to avoid bruising the fruit. The wagons or carts on which the fruit is hauled to the packing house should not be of the usual springless type, and in loading and unloading the boxes should be handled with all care. They should not be filled so full that part of their contents protrude, since such fruit will be injured by crates piled on top.

In the packing house the careful handling must be continued. All machinery should be arranged to cause a minimum of injury to the fruit, with elimination of all sharp corners, protruding nails, splinters, or other obstructions capable of breaking the rind of the fruit. A very good plan is to require pickers, packers, and others who handle the fruit to wear cotton gloves to avoid finger-nail scratches.

One of the most important matters to be guarded against is the accumulation of rotting fruit in and about the packing house. All rejected fruit should be removed daily and all field crates, wagons, and packing machinery should be kept clean, and those contaminated by rotting fruit dipped in some disinfecting solution.

There are many other details in this matter of careful handling in the packing and shipping operations, all of which have been treated in various other available publications to which the reader is referred, in particular to Farmer's Bulletin 696, "Handling and Shipping of Citrus Fruits."

ANTHRACNOSE.

The anthracnose fungus (*Colletotrichum gloeosporioides*), in

addition to the forms of disease already described, produces a soft rot of the fruit to a limited extent. Typical anthracnose spots first appear, and under favorable conditions the rot spreads so as to involve the entire fruit. In a majority of cases, however, anthracnosed fruit is rotted by *Diplodia* or blue mold, which gain entrance through the anthracnose lesions. Held under ordinary room conditions, a very large percentage of the anthracnose spots fail to continue their development, and an infected fruit ultimately dries up, unless attacked by one of the other fungi.

As already noted, the fungus involved in this type of decay is only weakly parasitic, and uninjured fruit from healthy trees will be practically free of it. To prevent loss from this source the measures outlined above for blue mold will be applicable.

Several fungi of decidedly minor importance have been noted on rotting fruit, for the most part merely secondary (*Aspergillus* spp., *Rhizopus* sp.), though occasionally as primary agents, but always entering through wounds. Control will be the same as for blue mold.

BLOSSOM END ROT.

Two types of blossom end rot have been distinguished in Porto Rico, which for convenience have been designated as the pink and the black. Both have similar external symptoms, the course of the infection and rotting is the same, and control measures are identical. Apparently only oranges are subject to attack, the navel orange to some extent, but other varieties more in particular. The disease is more prevalent, or at least causes most visible damage, at the beginning of the shipping season, infected fruit becoming less and less as the season advances and seldom being found after November. The disease is more prevalent in some years than in others, apparently dependent upon certain climatic influences.

The only marked external symptom is the bright orange color of infected fruit in marked contrast to the yellow or yellow-green of the normal fruit. Porto Rican oranges, at least those from cultivated groves, seldom become so highly colored. Following the high coloring, and sometimes to be seen before the fruit drops, there appears a brown, sometimes slightly sunken area at the blossom end, from four to ten millimeters in diameter.

On cutting into the fruit there is most commonly found a brown rot along the rag, which ultimately involves the sections as well. In the early stages there appears merely a discoloration in the skin

and underlying rag tissue, which later assumes a pink color, followed by the brown rotting. The apparent cause in this case is a fungus (*Fusarium* sp.). This form has been isolated a considerable number of times and by inoculation has been found capable of producing the rot. Investigations of this disease have shown that the anthracnose fungus is commonly present as a secondary agent, the rot progressing very slowly until this form enters.

Occasionally instead of the pink staining in the tissues at the blossom end there will be a black decayed area, which spreads even more slowly than the pink rot, and may remain confined to one section of the fruit only. The fungus in this case is known as *Alternaria citri*, and is common, though not serious, in California and Florida. The Fusarium type has been reported only from Porto Rico.

Infection in the case of both of these fungi occurs probably in the blossom, or while the fruit is very young. A certain percentage of infected fruit drops immediately, but in the others the fungus after a limited development becomes dormant until the fruit approaches maturity, and loses its power of resistance.

The complete life history of the causative fungi not having been worked out, control measures are somewhat uncertain, but will in the main consist of grove sanitation, the picking up of all drops, and removal of dead wood.

JUNE DROP.

A common phenomenon in commercial groves, and one which results in heavy losses at times, is the dropping of immature fruit. Following the bloom period there is always a heavy shedding of the newly formed fruit, and again in May or June there is very apt to be a second period, when dropping of fruit, by this time from an inch to two inches in diameter, occurs to a serious extent. A considerable portion of this dropping must be considered normal, the tree merely having set more fruit than it is capable of carrying through to maturity. If this natural thinning did not occur, steps to the same end would be necessary on the part of the grower.

However, much of the dropping must be considered abnormal, particularly that occurring during the second or June period. At this time many of the fallen fruit show irregular, brown, gumming areas on the surface and a brown stain at the blossom end. In the many cultures made of this class of material but one fungus has ever been found with any degree of regularity, *Collectotrichum*,

making it apparent that conditions other than fungus attacks are primarily responsible. Observations show that the chief factor involved is the moisture supply, the drier the weather prevailing at the critical time the greater the drop. Fruit lost under these conditions would naturally be attacked by the omnipresent anthracnose fungus, which is responsible for the browning and gumming

OIL BURNING OF FRUIT.

A very common form of injury to citrus fruits is one marked by a sinking of the tissue between the oil cells, causing them to project prominently. The sunken areas are normal in color at first, but finally become brown. The spots produced are irregular, may be one or several in number, and vary in size from the extent of a few oil cells to large portions of the surface. This type of injury, although noted on oranges, has been most serious on grapefruit.

FIG. 19.—Oil-burning on grapefruit.

The amount of fruit affectd varies from grove to grove and from time to time, being correlated with the amount of moisture present, and the nature of the handling received. It is commonly observed that the spotting occurs most seriously during wet weather, and that green fruit is more subject to it than that fully mature. It has been demonstrated in California, and verified by experiments here, that this type of blemish is due to the injurious action of the oil of the fruit itself, when liberated by bruising or other surface injury, in the presence of moisture. Even very minute quantities are sufficient to cause the burning.

After the initial burning there are no further developments unless rot sets in. Ultimate disposition of fruit of this character depends upon the packing-house management. In some instances where shipping rot is very prevalent it is discarded, but it is generally merely placed in the lower grades, and has been found to carry very well. The edibility of the fruit is, of course, not harmed.

Control.

Certain suggestions can be made which should be effective in reducing to a minimum losses from this source. Until the fruit is fully mature, avoid as far as possible picking when the fruit is wet, and when this is not practicable, at least keep the rain and dew off the picked fruit. Pile the field crates in the packing house so that a maximum of ventilation will be possible. Since the actual burning follows injuries, every precaution must be taken to prevent scratching or bruising.

RUSSETING OR TEAR-STAINING.

Russeting is caused by several distinct agents, most important of which are the rust mite and the withertip fungus. Rust-mite injury is typically brown to black, occurring on the side of the fruit exposed to medium light, shaded and full-lighted areas remaining clear. The causal agent in this case is a minute mite, or spider-like animal, which is readily controlled by one to three sprayings with lime-sulphur or other sulphur compound, at the time the trouble makes its appearance.

Russeting due to fungus infection is brown in color, slightly rough to the touch, and more apt to cover the fruit uniformly, and independent of shading. Infection very often occurs in lines or bands running from the stem to the blossom end in very characteristic manner. This appearance has resulted in the name, "Tear-staining." The markings are entirely superficial, and are produced by slight infections by the withertip and possibly other fungi. In most cases the source of the infection will be found in dead twigs above the fruit which harbor the fungus. The carrying qualities of the fruit are not lowered and there is no further injury, the loss arising from the necessity of placing all such fruit in the lower grades.

The points outlined for control of the withertip fungus in its other phases will also apply here. The pruning out of dead wood is of special importance.

SILVER SCURF.

A rather common form of blemish on citrus fruits is that known as silver scurf or "thrips marks." These are irregular silvery areas,

due to the breaking up of the epiderm into small irregular flakes or scales. That the injury is superficial is readily shown by the ease with which the scales may be removed, exposing the normal tissue beneath. Small fruit sometimes become misshapen, but ordinarily there is no harm other than the lowering of grades. This injury is readily distinguished from scab in that raised corky areas or conical projections are lacking.

A number of possible agencies have been considered as the cause, and all are probably involved at one time or another. Slight injuries when the fruit is young, rubbing against thorns or branches, and the use of too strong spraying solutions cause some of the markings. A large percentage is thought to be due to the work of minute insects known as thrips. In Florida a fungus is commonly found in connection with the scurfing, but is probably secondary. The program of grove sanitation, pruning, and sulphur spraying recommended for other more serious troubles should keep silver scurfing down to a minimum.

SPLITS AND CREASING.

Splitting is a mechanical injury due to unequal pressure between the inner and outer tissues of the fruit. It is thought to be caused in part at least by a succession of periods of drouth and wet weather, the rind being unable to keep pace with the growth of the pulp, when the moisture supply is suddenly increased after a shortage. Additional cultivation or irrigation during a drouth would probably obviate this trouble if it ever assumed serious proportions. At present only the naval orange, an unsatisfactory variety, is at all subject to it.

FIG. 20.—Creasing of orange.

Creasing (Fig. 20) is a similar type of injury in which there is a partial break only, the skin remaining whole, and the injury being apparent by a depression of the rind along the line of the break. The cause and control are the same as for splitting.

BUCKSKIN OR SHARK SKIN.

Buckskin is a disease of the epiderm or outer skin of the fruit only. The outer layer of cells is killed and takes on a characteristic gray, scaly appearance. The entire surface of the fruit is involved. An affected fruit ceases to grow and in addition to a very thick rind is generally lacking in juice so as to be of no economic value. Most affected fruit fail to reach any considerable size. Buckskin is readily distinguished from rust-mite injury, tear staining, melanose, and similar injuries to the surface by the fact that it covers the fruit uniformly, is light in color, and comparatively smooth to the touch.

It is more common on lower branches or in the center of the tree. The amount present varies greatly from year to year, being very abundant one season and entirely lacking the next. In some cases spraying with Bordeaux mixture has apparently increased the amount, and in others has been reported as preventing it. It is altogether probable that several causes operate to produce the same effect. Those suggested have been the combined action of mites and surface-growing fungi, and the alternation of periods of drouth and heavy rainfall.

SMOKY FUNGUS (*Leptothyrium* sp. ?)

This fungus is of comparatively common occurrence, particularly on the orange, but is, as a rule, overlooked by the grower. It forms irregular and often very extensive patches on the surface of the fruit. The fungus growth is confined, for the most part, to the regions between the oil cells, dimming the color of the fruit, and giving rise to the common name. Because of this scanty habit of growth, it has generally been considered as dust only. The brushes in the packing houses generally eliminate it sufficiently well, so that there is no loss through lowering of grades. Where lime-sulphur is used in the grove, this fungus will be sufficiently well controlled.

MINOR DISEASES AND DEFECTS.

Many minor diseases and blemishes occur on the fruit, leaves, and twigs, but all are either of so slight importance as to warrant no control measures, or are checked by operations designed to prevent more important troubles.

A leaf spot (Fig. 21) due to an as yet undetermined fungus occurs widespread, but on hardly more than a few leaves at a time. The spots are brown, slightly raised, plateau-like appear the same on both leaf surfaces, and vary in size up to one centimeter in diameter. Their shape is circular to irregular. Larger and older spots become gray at the center with definite, raised brown margins.

FIG. 21. — Spots on grapefruit leaves due to *Phyllosticta* sp.

A peculiar condition of terminal leaf clusters has been observed in grapefruit nursery trees, in which all the leaves are distorted, stunted, and one surface (generally the back) glazed. This is thought to be due to thrips injury.

Spraying injury may assume several forms. Bordeaux causes a burning of young unfolding tips, and on more fully developed leaves may produce a pitting (Fig. 22), the pits corresponding to the position of drops of spray material responsible for the burning. Lime-sulphur may cause injuries on fruit, with much the appearance of anthracnose spots, which fungus in fact generally follows.

FIG. 22.—Spotting due to Bordeaux mixture.

Knots in the rind occur in grapefruit, and possibly the orange. They are characterized by a slight raising of the skin, which feels hard. Internally they show as gum infiltrated areas. The cause is not known.

A common blemish on grapefruit consists of minute (a millimeter, more or less, in diameter), brown to black, slightly depressed markings on the surface. The epiderm only is affected, but since

the marks occur in great numbers the appearance of the fruit is marred. The cause is difficult to ascertain because of the absence of any fungus-fruiting bodies, and the minute character of the markings, which are probably due, however, to surface infections by some fungus, much after the nature of melanose. The withertip fungus is again suspected.

Leaves may show at times, irregular brown, very slightly raised areas which are caused by gum infiltrations. The initial cause is not certain, but in some instances is due to sun-burning.

Citrus trees commonly harbor a great variety of mosses, lichens, and other epiphytes (air plants). Several species of orchids and bromeliads grow on the trunks and limbs, as well as a number of ferns. None of these plants do any harm to the trees. On the leaves, several simple moss-like plants occur abundantly in shaded and damp parts of the grove, and may have some slight influence by cutting off light. Circular, silvery spots due to lichen growth (*Strigula* sp.) occur in similar situations.

Various minor fungi, occurring for the most part on dead wood, are recorded in the appendix. The several entomogenous fungi, which might at times, because of their abundance, come under the suspicion of the grower, are also enumerated and briefly described at the same point. It is desirable that the grower should be familiar with these beneficial forms, in order that such protection as is possible may be given them.

BIBLIOGRAPHY.

The brief list of references given here merely aims to mention such publications as it is thought will be of value to the Porto Rican citrus growers, and which are at the same time easily obtainable. There is, of course, a wide range of other publications on all the various phases of the subject, in large part technical, the substance of which, however, will be found in the ones listed.

Citrus fruits and their culture. Hume. Published by Orange-Judd Co., New York.

Citrus fruits. Coit. Published by McMillan, New York.

California citrus culture. Cooke. Published by California State Commission of Horticulture, Sacramento.

Citrus scab in Porto Rico. Bul. 17, Insular Experiment Station.

The handling of Porto Rican oranges, grapefruit, and pineapples. Bul. 7, Insular Experiment Station.

Scale insects and their control. Circular 9, Insular Experiment Station.

Wood rot of citrus trees. Circular 10, Insular Experiment Station.

Preparation of lime-sulphur. Circular 13, Insular Experiment Station.
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Citrus diseases. *In* report of the Insular Experiment Station, 1916–17.
Propagation and marketing of oranges in Porto Rico. Bul. 4, Mayagüez Experiment Station, Porto Rico.
Insects injurious to citrus fruits and methods for combating them. Bul. 10, Mayagüez Experiment Station.
Handling and shipping citrus fruits in the Gulf States. Farmer's Bul. 696, U. S. Dept. of Agriculture.
Citrus fruit improvement. Farmer's Bul. 794.
First report of the San Pedro citrus pathological laboratory. San Pedro, Isle of Pines, Cuba.
Diseases of citrus fruits. Bul. 108, Florida Experiment Station.
Melanose and stem-end rot. Bul. 111, Florida Experiment Station.
Injury to citrus trees by ground limestone. Bul. 137, Florida Experiment Station.
Dieback, or exanthema of citrus trees. Bul. 140, Florida Experiment Station.
Citrus diseases of Florida and Cuba compared with those of California. Bul. 262, Cal. Agricultural Experiment Station.
A spotting of citrus fruits due to the action of oil liberated from the rind. Bul. 266, Cal. Agricultural Experiment Station.
The June drop of Washington navel oranges. Bul. 290, Cal. Agricultural Experiment Station.

APPENDIX I.

FORMULAS.

BORDEAUX MIXTURE.

Copper sulphate (bluestone)	3 pounds.
Live-lime	3 pounds.
Water	50 gallons.

The most convenient method of making Bordeaux, at least when large quantities are needed, is by preparing stock solutions. These are made by dissolving one or two pounds of copper sulphate in each gallon of water, to any amount desired, and similarly with the lime. These solutions may be kept for considerable lengths of time in their separate containers. Metal containers should not be used for holding them. The copper is best dissolved by placing it in a sack and hanging so it will be suspended just beneath the surface of the water over night. If needed in a hurry hot water must be used.

To prepare Bordeaux from the stock solutions, add three gallons of the copper solution to approximately forty-six gallons of water, and then stir in three gallons of lime stock, or a gallon and

a half of each stock if they are double strength. The concentrated solutions should not be mixed directly.

It is essential that all the copper be neutralized, since free copper will cause serious burning. This formula ordinarily provides a wide margin of safety, but a weak solution of ferrocyanide of potassium can be used for testing where there is any doubt. A black color, showing when a few drops are placed in a saucerful of the Bordeaux mixture to be tested, indicates free copper and more lime must be added.

BORDEAUX PASTE.

Commercial Bordeaux paste or powder can be used by adding sufficient water to make up a paste of the necessary consistency, or it can be prepared as follows:

One pound of copper sulphate is dissolved in one gallon of water. Two pounds of live lime are slaked in one-half gallon of water. The two mixed together give a satisfactory compound. This material deteriorates rapidly and should be made up only as needed. Stock solutions for Bordeaux mixture can be conveniently used by taking proper amounts of each.

LIME-SULPHUR.[1]

Unslaked lime	50 pounds.
Sulphur	100 pounds.
Water	50–60 gallons.

Any of the several form of sulphur, sulphur flours, flowers of sulphur, or powdered commercial sulphur, will be found to yield satisfactory results. The only requirement in this connection is pure sulphur (at least 99 per cent), no matter what its form.

This combination has been found to give most uniform results. It can, of course, be modified to any extent desirable as long as the ratio of 1–2–1 between lime, sulphur, and water is maintained. In the case of the water, enough should be used to allow for evaporation or else more added from time to time so that there will be approximately fifty gallons of product at the finish. Using more than fifty gallons of water will give a concentrate of less density, but one containing less sediment.

Equipment.—A great variety of kettles or boilers can be obtained for the preparation of lime-sulphur and in any size, adapted to the need of each grower. The large iron kettles used in the old open-

[1] Partial reprint of Circular 13, Insular Experiment Station, the English edtiion of which is exhausted.

pan method of sugar making have been used successfully in a number of instances. On a large scale an upright 5-horsepower boiler supplying steam to a number of 50-gallon barrels works very well. Plans for the erection of a lime-sulphur plant of any size are available, and can be supplied to anyone wishing them. Whatever the type of cooking outfit used the size of each batch should be sufficient to fill it not over two-thirds full, for otherwise there is danger of the solution boiling over the top.

Preparation.—Weigh out the required amounts of lime and sulphur (it is essential that the weighing be accurate in order to obtain the proper ratio), and place the former in the kettle or boiler with sufficient water to slack it. Start the fire beneath the boiler at the same time, and as soon as the slacking process is well under way, add the sulphur, either dry or as a paste. Better results, however, will be obtained if it is stirred up with water first to form a thin paste and all lumps broken up. A sifter or screen will help in this latter regard. When the two ingredients are thoroughly mixed and the slacking is completed, add enough water to bring up to the total amount required (50–60 gallons). If steam is used, no further additions are necessary, but otherwise water must be added from time to time, to make up for evaporation. If desired, the sulphur paste may be placed in the boiler first, followed by the water, and finally the lime. Results will be the same.

Stirring is quite essential, particularly during the first half of the boiling. Care should be taken to break up all lumps of sulphur. Working over open kettles will necessitate the use of goggles, the fumes and sulphur particles being injurious to the eyes. To maintain the proper volume a measuring stick adapted to the particular cooker in use will be found desirable.

The time required for boiling will vary somewhat, but is approximately an hour, or until the sulphur granules are all dissolved. To ascertain whether this point has been reached, take a sample and pour from one container to another, observing closely. If at the proper stage the solution will be of a dark-red color and free of sulphur granules. Too much or too little boiling will increase the amount of sediment, but of the two the latter exreme is preferable.

The soluion (concentrate) may be diluted and used immediately, or may be stored for future use. In either case it should be strained to remove the sediment, using a screen of from 30 to 40 meshes to the inch. The sludge which passes through is not objectionable.

The principal points to be guarded against during storage are evaporation, exposure to the air, and presence of acids, surplus lime, or other chemicals in the containers. Clean barrels may be used, and if it is not possible to close them air-tight a layer of heavy oil will protect the concentrate. This can be skimmed off before using the lime-sulphur. Changes in temperature will not affect the material.

Dilution.—This is the most important point in the entire process of using lime-sulphur, and is of equal importance whether the commercial brands or the home-made material be used. Two solutions may appear to be the same, but in fact may be found to vary greatly in density, so that unless dilution is properly carried out, burning may result. A concentrate will change in density from time to time due to evaporation, and it is therefore essential that a test be made each time portions of it are used. Safe and satisfactory dilutions are obtained by the use of a simple instrument known as the hydrometer (Fig. 23). These are made for a wide range of uses, and hence to obtain best results one especially adapted for lime-sulphur work should be used.[1] The best type is graded in two scales, the specific gravity or decimal scale, and the Baumé or degree scale. The concentration of lime-sulphur solution is generally given in terms of the Baumé scale but the other is necessary in making the calculations for final dilutions.

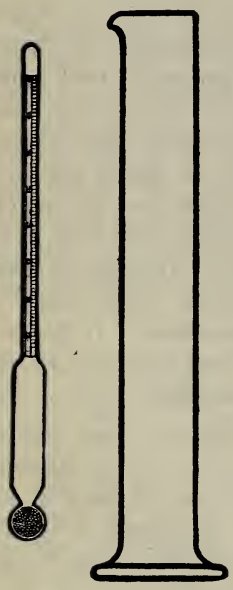

FIG. 23. — A lime-sulphur hydrometer showing the Baumé scale. On the right a cylinder of the type sold with the instrument. Any vessel of sufficient depth may be used in its place.

To obtain a spray of any certain concentration, obtain the density of the concentrate with the hydrometer, and then divide the decimal of this reading by the decimal of the density of the spray desired, and dilute according to the figure obtained. For example, if the concentrate has a density of 1.283 (32° Baumé) to obtain a spray solution of 1.026 (a 1–10 spray) the figure .283 is divided by .026, giving 10 plus, the number of dilutions.

[1] These may be purchased together with the cylinder for about one dollar from the Bausch and Lamb Optical Co., Rochester, N. Y.; Arthur Thomas, Philadelphia; Eimer and Amend Co., New York; and other dealers in scientific supplies.

It should be noted that this gives the total number of dilutions, and that the amount of water used would be nine parts to one of concentrate.

In using the hydrometer care must be taken to see that it is cleaned between readings. A little vinegar will help if it becomes coated with lime. The material to be tested should be free from sediment and at air temperature. Best results will be obtained by testing several days after the solution has been made. Read the hydrometer scale at the general surface of the liquid, and not at the point to which the liquid is drawn up by capillary attraction about the stem.

While it is preferable that the proper dilution be figured out from direct readings, using the rule given above, the following table has been prepared as being more convenient. It gives the approximate dilutions necessary to prepare the strengths most commonly employed. Thirty-two degrees Baumé has been taken as the standard strength

Lime-Sulphur Dilution Table.

If concentrate tests		To Make up One Hundred Gallons of Spray Mixture								
B.	Sp. Gr.	At 1-10 use Gals. Pts.	At 1-15 use Gals Pts.	At 1-20 use Gals. Pts.	At 1-25 use Gals. Pts.	At 1-30 use Gals. Pts.	At 1-35 use Gals. Pts.	At 1-40 use Gals. Pts.	At 1-50 use Gals. Pts.	At 1-75 use Gals. Pts.
25°	1.208	13-4	9-0	6-6	5-3	4-4	4-0	3-3	2-6	1-7
26°	1.218	13-	8-5	6-3	5-1	4-2	3-6	3-2	2-5	1-6
27°	1.229	12-3	8-2	6-2	5-0	4-1	3-5	3-0	2-4	1-5
28°	1.239	11-7	7-7	5-7	4-6	3-7	3-4	3-0	2-3	1-4
29°	1.250	11-3	7-4	5-5	4-4	3-6	3-3	2-7	2-2	1-4
30°	1.261	10-7	7-1	5-3	4-2	3-5	3-2	2-6	2-1	1-3
31°	1.272	10-3	6-7	5-1	4-1	3-4	3-1	2-5	2-	1-3
32°	1.283	10-0	6-5	5-	4-0	3-3	3-	2-4	2-	1-3
33°	1.295	9-5	6-3	4-6	3-7	3-2	2-7	2-3	1-7	1-2
34°	1.306	9-2	6-1	4-5	3-6	3-1	2-6	2-2	1-7	1-2
35°	1.318	8-7	5-7	4-4	3-4	3-	2-5	2-2	1-6	1-1
Specific Gravity		1.026	1.016	1.014	1.011	1.009	1.007	1.004	1.002	1.001

NOTE.—One hundred gallons is the total dilution. To find the amount of water to be used subtract the amount of concentrate indicated from one hundred.

Sp. Gr. = Specific gravity.

Compatibilities.

It is very often desirable to combine other materials with the lime-sulphur, especially poison for biting insects. This permits of a saving of time and consequently of money. Lead arsenate (neutral) may be used in this manner without any fear of injuries resulting, although it does produce a chemical change in the lime-sulphur which shows as a darkening of the solution. As a matter of fact, the addition of the arsenate actually increases the fungicidal value of the sulphur.

Substances other than the lead arsenate should be used with extreme caution. Those of an acid nature—Paris green, for exampl—are dangerous, and even an acid lead arsenate should be avoided. Lime-sulphur and soap form an inefficient but non-injurious combination. Sulphur and oil emulsions are dangerous if used together, the emulsion being destroyed and free oil liberated.

DISINFECTANTS.

For disinfecting field crates, pruning instruments, and other equipment, the following may be used:

Copper sulphate.—Used as a solution made up at the rate of four pounds of copper to one hundred gallons of water.

Corrosive sublimate (mercuric bichloride).—Used in solution at the rate of one part of the poison to a thousand of water. The most satisfactory method of obtaining this substance is in the form of tablets to be purchased at most drug stores. A tablet in a pint of water gives a solution of the desired strength.

Formaldehyde.—Formaldehyde or formalin is purchased in liquid form, forty per cent strength. For disinfecting purposes one part of this stock is to be added to ninety of water.

APPENDIX II.

CITRUS FUNGI.

A considerable number of fungi have been collected on the leaves, fruits, twigs, and other parts of the different citrus species. A list is given here to afford some idea of the prevalence and distribution of the various forms determined.

Aspergillus flavus Link. Green mold on rotting fruit, generally secondary. Not common.

Aspergillus niger Van Tiegh. Black mold on rotting fruit, generally secondary. Not common.

Capnodium citri Berk. & Desm. Very common in all sections, forming black, superficial, sooty layers over fruit, leaves and twigs of all types of citrus fruits. Follows turtle-back, hemispheric scale, wooly white fly, and other insects. Not parasitic.

Cephaleuros virescens Kunze. Forming spots on living leaves, twigs and bark of lime,[1] lemon, sweet lemon, sweet and sour orange, and grapefruit. Very common in all sections.

Cladosporium citri (?) Massee. On living leaves, twigs, and fruit of grapefruit, lemon (all types), sour orange, sweet orange (rare), king orange. Common.

Cladosporium herbarum Link. On dead leaves, or in old anthracnose spots, Río Piedras, Pueblo Viejo. Saprophyte.

Colletotrichum gloeosporioides Penz. On living leaves, twigs, and fruit, and dead citrus material of all kinds. The cause of leaf spotting, withertip, fruit, spotting, fruit rot, and russeting. Exceedingly common everywhere, and on all host species.

Corticium confluens Fr. On dead wood of grapefruit, Campo Alegre.

Corticium salmonicolor B. & Br. Causing the death of branches of grapefruit and orange, Pueblo Viejo, Garrochales, Espinosa, Bayamón, Río Piedras.

Daldinia concentrica (Bolt.) E. & E. On dead citrus wood, Pueblo Viejo, Palo Seco, Garrochales, Espinosa.

Diplodia natalensis Evans. Causing fruit rot, twig blight, bark canker of orange and grapefruit, and collected in fruiting condition on mummified fruits twigs, bark, and roots, in all sections of the Island.

Hypoxylon fuscopurpurea Berk. On dead grapefruit branches, Campo Alegre.

Lecanidion cyaneum (Cooke) Sacc. On dead twigs, grapefruit, Campo Alegre.

Leptothyrium pomi (?) (M. & F.) Sacc. On fruit of orange and grapefruit, common.

Myrothecium verrucaria (A. & S.) Ditm. On dead grapefruit leaf, Río Piedras.

Nectria episphaeria (Tode) Fries. On dying bark, grapefruit, following *Corticium salmonicolor*, or other injury, Bayamón.

Penicillium crustaceum L. On dead grapefruit wood, Sabana Llana.

Penicillium digitatum (Fr.) Sacc. Olive-green mold, attacking all species of citrus fruits. Exceedingly common everywhere.

Penicillum italicum Wehmer. Blue-green mold on all types of fruit. Not common.

Peniophora cinerea Fr. On dead wood and twigs, orange and grapefruit, Pueblo Viejo, Campo Alegre, Espinosa, Bayamón.

Peniophora flavido-alba Cooke. On dead wood, grapefruit, Vega Baja.

Pestalozzia guepinia Desm. On grapefruit leaves, Espinosa.

Phomopsis citri Fawcett. On living leaves, twigs, and fruit; and dead twigs of orange and grapefruit, Río Piedras, Palo Seco, Bayamón.

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[1] The following scientific names for the citrus species are recognized:
Citrus decumana, grapefruit, pomelo.
Citrus sinensis, sweet orange.
Citrus limonia, lemon, sweet lemon, rough lemon.
Citrus aurantium, sour orange.
Citrus aurantifolia, lime.
Citrus nobilis, king orange, mandarine, satsuma, tangerine.

Polystictus occidentalis Klotzsch. On grapefruit, in connection with wood rot, Sabana Llana.

Polystictus pinsitus Fries. On grapefruit (dead wood), Espinosa.

Rhizopus nigricans Ehr. Causing a rot of fruit. Not common.

Schizophyllum commune L. Common as a wood-rotting fungus, and in one instance as a fruit rot.

Sclerotium Rolfsii Sacc. On dead grapefruit wood, and as the cause of crown rot of seedlings, Bayamón, Río Piedras.

Septobasidium lilacinum Burt. A superficial papery layer around grapefruit trunks, Bayamón, Espinosa, Palo Seco.

Stereum albo-badium Schw. On dead limbs, grapefruit, Espinosa, Vega Baja.

Stereum coffearum B. & C. On dead wood, sour orange, Río Piedras.

Stictis radiata Pers. On dead twigs, grapefruit, oranges, Sabana Llana, Espinosa, Campo Alegre.

Tryblidium rufulum Spreng. Very common on dead wood, particularly prunings left beneath the trees.

Ustilina vulgaris Tul. In connection with root rot of orange and grapefruit, Palo Seco.

ENTOMOGENOUS FUNGI.

Aschersonia cubensis B. & C. Growing on various scale insects, which are generally undeterminable, in the form of hemispherical masses, two to three millimeters in diameter, scattered, commonly on lower leaf surfaces, buff, finally red at the center. Common in all districts.

Aschersonia turbinata Berk. Very similar to the above, except that the fungus masses are top-shaped, attacking various scales. Common.

Cephalosporium lecanii Zimm. Forming a white powdery layer on hemispheric and turtle-back scales,[1] Sabana Llana.

Microcera Fujikuroi Miy. & Saw. On Florida red, and chaff scales, on orange and grapefruit. Infected insects assume a bright scarlet color, the fungus appearing as small erect, pink, flask-shaped bodies, Mayagüez, Bayamón, Pueblo Viejo. "The pink-headed scale fungus."

Myriangium duriaei Mont. & Berk. Forming small, sessile, black masses on white and purple scale on lime, lemon, orange, and grapefruit. "The black fungus." Common.

Scoleconectria coccicola (E. & E.) Seaver. On white and purple scale, forming small white masses, and finally minute spherical, gray to buff perithecia. Common. "The white-headed fungus."

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[1] The various scales mentioned as hosts of the above fungi are technically known as follows:

Star scale, *Vinsonia stellifera* Westu.).
Hemispherical scale, *Saissetia hemispherica* (Targ.).
Turtle-back scale, *Saissetia oleae* (Bern.).
White or snow scale, *Chionaspis citri* Comst.
Chaff, or articulate scale, *Pseudaonidia articulatus* (?).
Florida Red Scale, *Chrysomphalus aonidum* (Linn.)
Purple scale, *Lepidosaphes beckii* (Newm.)

Septobasidium spongia (B. & C.) Pat. Forming a brown weft-like layer over white and purple scales, and often reaching an extent of several inches on fruit, leaves, and twigs. Found sparingly in all districts.

Sphaerostilbe coccophila (Desmaz) Tul. On purple, and chaff scales, producing small, red, flask-shaped fruiting bodies, and later clusters of minute, scarlet spherical perithecia. "The red-headed fungus." Common everywhere.

Tubercularia coccicola Stevenson. Forming sessile pink masses on white and purple scales, grapefruit, Espinosa, Río Piedras, Pueblo Viejo, Bayamón. Common. "Pink scale fungus."

In addition to these named species at least three others occur more or less commonly, attacking for the most part the white and purple scales. These are (1) a form producing a thin black layer with white margin, over large areas on trunk, and limbs; (2) a form producing small, globular, gray to black fruiting bodies borne on a short, erect stalk; and (3) a form consisting of small masses of loose brown mycelium (not forming continuous patches as does the *Septobasidium*).

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